Cedar River Chinook Salmon (*Oncorhynchus tshawytscha*) Redd Survey Report, 2001:
Spatial and Temporal Distribution of Redds, Carcass Age, Sex and Size Frequency Distributions, Redd Residency Duration and the Incidence of Redd Superimposition on Incubating Chinook Redd Mounds

by

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Introduction

On March 24, 1999, Puget Sound chinook salmon (*Oncorhynchus tshawytscha*) were listed as threatened under the Endangered Species Act of 1973 (Fed. Reg, Vol. 64, 14308). Cedar River chinook salmon are among the 38 populations (stocks) that comprise the Puget Sound Evolutionary Significant Unit (ESU) for chinook. In addition, Cedar River chinook salmon are one of 22 Puget Sound chinook populations that are being considered for recovery efforts by the Puget Sound Chinook Technical Recovery Team. Many natural populations within the Puget Sound ESU are currently small enough that genetic and demographic risks are likely to be high (Myers et al. 1998). The Cedar River was officially designated as a critical habitat component of the Puget Sound chinook salmon ESU on February 16, 2000 (Fed. Reg. Vol. 65, 7764).

A number of questions concerning the specific life history patterns and habitat preferences for Cedar River chinook salmon remain unanswered. An enhanced understanding of the life history strategies and timing of Cedar River chinook will allow resource managers to make more informed decisions regarding fisheries management, water management and land management activities as they relate to habitat suitability and chinook recovery in the Lake Washington Basin. Currently, there are many ongoing formal investigations concerning the behavior, survival and habitats of Cedar River chinook salmon. The primary goal of this report is to convey the results and conclusions from an ongoing study investigating the spatial and temporal distribution of Cedar River chinook spawning activity and the size and age characteristics of the spawning population.

Background

The Cedar River is the largest tributary inhabited by chinook salmon in the Lake Washington/Lake Sammamish Basin (Williams et al 1975). Originating in the Cascade Mountains, the Cedar flows through Seattle's Municipal Watershed, the Town of Maple Valley and the City of Renton before emptying into the southern end of Lake Washington. The Cedar River provides critical habitat for a wild population of threatened chinook salmon. Other salmonid species inhabiting the Cedar River include *coho (O. kistuch*) and sockeye/kokanee (*O. nerka*) salmon, rainbow (*O. mykiss*) and cutthroat (*O. clarki*) trout, bull trout (*Salvelinus confluentes*), mountain whitefish (*Prosopium williamsoni*) and pygmy whitefish (*Prosopium coulteri*). Many of these populations contain individuals exhibiting anadromous, adfluvial and/or resident forms. Occasional stray adult salmonid fishes found in the Cedar include chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), and Atlantic salmon (*Salmo salar*). The distribution of anadromous salmonid species in the Cedar is currently limited to the mainstem and tributary habitats below the Landsburg Diversion Dam which currently blocks access to approximately 17 miles of formerly occupied habitat. At Landsburg, water from the Cedar River is diverted for municipal and industrial uses. The Cedar supplies approximately two thirds of the freshwater used by Seattle and the surrounding cities and communities.

Beginning in the mid-1960's, the Washington Department of Fish and Wildlife (WDFW) has conducted regular surveys to count fall spawning adult salmon in the Cedar River. Figure 1 shows historical Cedar River chinook escapement index estimates derived from fish count surveys using the Area Under the Curve methodology (Perrin and Irvine, 1990). It is important to note that millions of juvenile hatchery chinook salmon were introduced to the system between 1944 (Ajwani,1957) and 1965 (WDFW hatchery planting records). The recent trend in escapement estimates for Cedar River chinook indicates that the population is continuing to decline with the five lowest escapement estimates occurring in the last eight years. This negative trend in recruits per spawner must be reversed if chinook are to persist in the Cedar River.

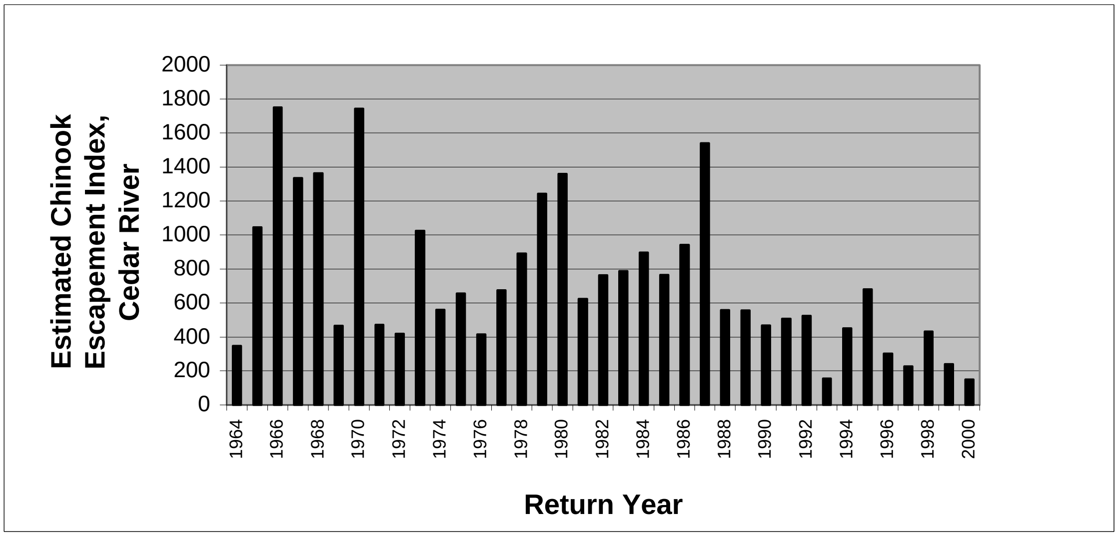

Figure 1. Historic escapement index estimate for Cedar River chinook based on fish counts and Area Under the Curve methodology.

Prior to 1999, chinook surveys in the Cedar River were limited to live fish counts recorded as part of the annual sockeye spawner surveys. In August 1999, WDFW staff requested that Seattle Public Utilities (SPU) initiate the first chinook redd surveys in the Cedar River. In response, a cooperative effort between SPU, WDFW, the Muckleshoot Indian Tribe (MIT) and King County (County), was initiated to document the spatial and temporal distribution of chinook spawning in the mainstem of the Cedar River . The primary goals of the first annual Cedar River chinook redd survey program (1999) were to: 1) develop a better understanding of the spatial and temporal distribution of chinook spawning activity in the Cedar River, 2) generate an alternative escapement estimate for returning Cedar River chinook salmon, and 3) provide information that may be useful in evaluating the effectiveness of the Cedar River sockeye broodstock collection protocol at minimizing adverse effects on chinook migration and spawning (Burton 2000).

In 2000, additional personnel commitments from SPU and the County and the involvement of biologists from the National Marine Fisheries Service (NMFS) allowed for a more robust data collection protocol including detailed descriptions of the physical and spatial characteristics of spawning locations and specific information regarding numbers of spawners per redd and redd residency duration. In addition, a preliminary assessment of sockeye spawning activity in the vicinity of incubating chinook was developed using weekly observations on all identified chinook redds. (Burton et al. 2001).

In 2001, chinook redd survey protocols were initially intended to include information for redd locations, spawn timing, spawning habitat characteristics, sockeye redd superimposition on chinook redds and the population's size/age composition. However, due to the relatively large escapement (398 redds), the suite of desired information could not be accommodated by the available staff and time. Therefore, a cooperative decision was made between resource managers and SPU and WDFW funding sources (The Cedar River Instream Flow Commission (IFC) and the Cedar River Anadromous Fish Committee), that data would be collected according to the following priority list: 1) spatial and temporal distributions of redds, 2) scale collection from identified chinook carcasses, 3) sockeye redd superimposition and 4) chinook spawning habitat characteristics. Water velocities, distance to shore and substrate sizes were not measured in 2001 due to the time requirements to document the top 3 priority data sets.

Specific information on the temporal and spatial distribution of Cedar River chinook redds can be used to improve our understanding of the effects of stream flow on the time of spawning, spawning site selection, and susceptibility of chinook redds to scour and dewatering. Long-term data sets for chinook redd characteristics in the Cedar River should allow biologists to identify trends in spawning activity as it relates to stream flow. For example, long-term data sets for chinook spawning locations, spawn timing and fish counts can be used (along with other studies) to develop correlations between these variables and stream flow. Long-term data sets for chinook spawning habitat could also be helpful in the development of river specific spawning habitat suitability indices for Cedar River chinook.

Chinook redd surveys also provide valuable information that is not directly related to stream flow. Observations regarding the temporal and spatial distributions of chinook spawning can be used to help avoid or minimize the effects of sockeye broodstock collection activities on migrating and spawning chinook. An enhanced understanding of habitat preferences for spawning chinook can assist land managers in prioritizing restoration projects and related land acquisitions. Additionally, an annual redd count can serve as an alternate approach to estimating annual escapement for the Cedar River chinook population. These escapement estimates can be used to generate long-term trends in population size which, in turn, can be used to evaluate the effectiveness of local recovery actions. Future surveys and analyses can be designed to address specific data needs or study questions as new priorities are recognized and developed by the Cedar River Instream Flow Commission and other natural resource institutions concerned with Cedar River fish populations.

Methods and Materials

Redd Surveys

Chinook redds in the Cedar River mainstem were located from inflatable rafts and marked with flagging to enhance relocation and to prevent double counting. Chinook redds in side-channel and tributary habitats were located and marked using foot surveys. Information recorded for each verified chinook redd included: redd number, spawning date, redd location (longitudinal), redd depth, number and sex of spawners, redd residence time for spawners, proximity to previously spawned redds and stream habitat type. Observations regarding chinook activity in the immediate vicinity of the WDFW sockeye broodstock collection facility (SCBF) were also recorded. After identification, incubating chinook redds in the mainstem and side-channel habitats were surveyed twice a week to identify and describe sockeye spawning activity on chinook redd mounds.

Redd surveys in 1999 indicated that the majority of Cedar River chinook females remain in close association with their redds for at least seven days after the initiation of digging. Using this information we believed that one full river survey per week would suffice to accurately estimate the total number of chinook redds in the Cedar. However, in 2000, a substantial number of redds that appeared to be spawned by chinook were observed without spawning fish. Survey protocols require that observed redds are accompanied by one adult female chinook before being designated as chinook redds. This strategy is particularly important in the Cedar River where sympatric populations of spawning sockeye and coho salmon can lead to the misidentification of the parent species for chinook redds that are not accompanied by spawning or spawned out adults. Therefore, full river surveys were performed twice a week in 2001 to help determine the minimum survey frequency necessary to accurately enumerate chinook redds. In addition, the largest Cedar River chinook escapement in over a decade required 2001surveyors to perform twice weekly surveys to enable the collection of the desired data sets. Twice weekly surveys should minimize the probability of detecting chinook redds after the female parent has expired and/or departed.

In addition to the formal chinook redd surveys, supplemental observations concerning chinook spawning locations were made by biologists from WDFW and MIT. Each Tuesday, WDFW, KC, and MIT raft teams surveyed Cedar River mainstem and sidechannel habitats to count live and dead sockeye and chinook salmon. The locations of chinook redds observed during WDFW and MIT fish count surveys were forwarded to SPU staff.

Chinook redd surveys and WDFW fish count surveys were performed concurrently for the weeks between August 15th to September 10th. After substantial chinook spawning activity had been observed, redd surveys and fish count surveys were performed separately. For redd surveys between September 13th and November 15th, the mainstem and sidechannel habitat was divided into 3 survey reaches including; 1) Landsburg aqueduct to Railroad Bridge (RM 21.4 to RM 13.4), 2) Railroad Bridge to Earthquake

Landslide (RM 13.4 to RM 5.0) and 3) Earthquake Landslide to the Slackwater Takeout near Lake Washington (RM 5.0 to RM 0.2). In addition, occasional foot surveys of the habitat between Landsburg and the aqueduct were performed to verify that chinook are not able to pass above the aqueduct crossing.

The first two mainstem survey reaches were surveyed by SPU and WDFW staff twice per week with the upper reach surveyed on Mondays and Thursdays and the middle reach surveyed on Tuesdays and Fridays. The lowest survey reach was surveyed by KC staff once per week on Tuesdays. In addition, KC and WDFW staff performed regular surveys of tributary habitats including Peterson, Taylor, Rock and Walsh Creeks. Tributaries were walked once per week and reaches surveyed typically consisted of the first 1000 feet upstream from the confluence with the Cedar River (see tributary maps) (Priest, 2002).

It should be noted that redd detection efficiency is directly related to light conditions, instream flow levels (depth), and river turbidity. Therefore, redd detection efficiency tends to decrease as the chinook spawning period progresses into November when river levels tend to rise and light levels tend to decrease.

Mapping and Redd Location Descriptions

All confirmed chinook redd locations were recorded and mapped on USGS maps and King County aerial photos. In 1999 and 2000, redd locations were mapped using GPS data transcribed to GIS maps. In 2001, redd locations were transcribed from aerial photos to a GIS data base map.

The Washington Dept. of Fisheries' Stream Catalog (Williams et al. 1975) was used to establish river mile (RM) locations for the mainstem Cedar River. Stream habitat types for redd locations were classified according to habitat typing techniques outlined in Bisson et al. (1982). Data from 2001 were compared to parallel data sets for 1999 and 2000.

Redd submergence depths were measured to the nearest centimeter. Depths were recorded for the deepest section of the redd pit and the shallowest area on the redd mound. Mound depth data were used to predict whether incubating chinook redds would be vulnerable to dewatering at HCP minimum instream flows (Appendix B) during the incubation period. Stage discharge relationships for shallow redd sites were used to predict the flow at which a given redd would begin to be dewatered. Only shallow redds that were spawned at levels above 260 cfs (HCP winter minimum flow) were evaluated for dewatering vulnerability. Predicted dewatering flows were compared to the HCP minimum flow regime to verify that minimum flows would fully protect incubating chinook from the adverse effects of dewatering.

Temporal spawner distributions for 1999, 2000 and 2001were compared and contrasted to the historical chinook run curve. The historic Cedar River chinook run curve was developed in 1995 at the request of the Cedar River Instream Flow Committee. Cascades Environmental Services (CES) and WDFW developed the annual and mean chinook run completion curves using WDFW Cedar River chinook spawning survey data collected between 1964 and 1994 (CES & WDFW, 1995). Due to the absence of long term Cedar River chinook redd survey data, the mean historic chinook run timing curve has been used here as a reference point for comparison to the chinook spawn timing observed in 1999, 2000 and 2001. It is recognized that the difference between live-fish count data in the historic run curve and redd count data for the temporal spawning curve may cause a lag in spawn timing as opposed to run timing. This is due to the fact that some fish count observations were made before enumerated fish had spawned.

Female Chinook Redd Residency, Survey Frequency and Spawners per Redd

Observed chinook redds were approached cautiously to count spawners associated with each redd. Chinook spawners were determined to be male or female according to fish color, body morphology and behavior. Redds that were initially observed with only one fish (typically a female) were not used to calculate the mean number of spawners per redd because we assumed that males had already departed. Incubating chinook redds were visited twice a week after initial observation and presence or absence of parent fish was recorded to determine the minimum time that female chinook remained in association with their redds. Presence or absence data were then used to generate an analysis to determine how many redds would have been missed if survey frequency was limited to one survey per week. Only data for the upper two mainstem survey reaches were used for the analysis because the lowest reach was only surveyed once per week. Biweekly mainstem survey data were filtered to retract every other survey in order to mimic the results of a weekly survey. If fish initially observed over their redd during a retracted survey were not attending their redds on subsequent surveys, the species determination for the redd was assumed to be unidentifiable by weekly surveys. This analysis was done twice, using early (Monday and Tuesday) and then late (Thursday and Friday) weekly surveys as the retracted surveys.

Assessment of the Incidence of Redd Superimposition on Chinook Redd Mounds

After chinook redds had been located and identified, they were visited twice per week to determine whether spawning sockeye had superimposed their redds on chinook redd mounds. Existing chinook redds were approached cautiously to avoid spooking spawning sockeye. Superimposed redds were assumed to be sockeye redds in cases where superimposed redds were observed without spawning adults. Chinook redds observed with one or more sockeye redds on top of, or overlapping with their redd mounds were enumerated. Observations were recorded during all surveys from August 29th to November 16th. Chinook redds superimposed on previously spawned chinook redd mounds were also enumerated.

Carcass Surveys

Chinook carcasses were identified and retrieved throughout the river during redd surveys. Side channels and gravel bars were examined for carcasses by foot. Overhanging vegetation, primarily Japanese Knotweed (*Polygonum cuspidatum*) along the rivers edge was thoroughly searched. Deeper pools were inspected from the raft and an extendable 16-foot spear was used to retrieve carcasses. A fish pugh was used to sort through sockeye carcasses in order to identify any chinook that may have been interspersed with the sockeye. Chinook carcasses that drifted downstream and became entrained on the sockeye brood stock collection weir at RM 6.5 were also collected and sampled.

Four scales were taken from each chinook carcass for age determination. The preferred area for scale collection was 2 to 4 rows up from the lateral line, on a line extending from the anterior edge of the anal fin to the posterior edge of the dorsal fin. Scales were mounted on scale cards and read by WDFW personnel. Ages were designated using the Gilbert-Rich system (total age of the fish with freshwater age as the subscript). Sex, length (postorbit to hypural plate; POH), and presence of identifying tags or marks were also recorded on the cards. Tails were cut on sampled carcasses to prevent re-sampling. A WDFW sockeye carcass sampling crew also sampled chinook carcasses that had not been previously sampled. Heads were removed from adipose fin clipped fish and checked at a later date for the presence of coded wire tags (CWTs). Only adipose fin clipped fish were checked for CWTs. Otoliths were taken from a representative portion of carcasses throughout the season.

All live chinook entering the trap at the sockeye broodstock collection weir between September 7, 2001 and September 20, 2001 were marked by WDFW personnel with a single opercle punch on the left operculum. Recoveries of marked carcasses were recorded in order to determine a recovery rate for male and female chinook carcasses.

Results and Discussion

Temporal Distribution for Redds from 1999, 2000 and 2001 Cedar River Chinook Spawning Periods

A total of 390 chinook redds were located and identified in the Cedar River mainstem and sidechannel habitats between August 15th and November 15th, 2001. In addition, 7 chinook redds were observed in Taylor Creek and 1 chinook redd was observed in Walsh Creek. The total chinook redd count for the Cedar River Basin (398 redds) was the highest redd count since redds surveys began in 1999. Total chinook redd counts for 1999 and 2000 were 180 and 53 redds, respectively. In 1999, Cedar River tributaries were not surveyed and tributary surveys in 2000 did not identify any chinook redds.

In 2001, the first active chinook redd was observed on September 4th (Figure 2). However, one redd was observed without spawning fish on August 29th and was identified as a chinook redd due to the large redd area, large substrate composition and the position in the river (near subsequent 2001chinook redds and immediately adjacent to chinook redd sites from 1999). In 2000, the first active chinook redd was observed on September 18th. The record low escapement in 2000 may have influenced the temporal spawning distribution because fish from small escapements have a lower probability of spawning in the tails of the potential temporal spawning distribution than return years with normal or larger than normal escapements. The commencement of chinook spawning was substantially earlier in 1999 with the first redd observed on August 18th and 2 more redds constructed prior to September 2nd.

Peaks in observed spawning activity were similar in 1999 and 2001 with the largest weekly redd counts occurring between October 3rd and October 9th. In 2000, peak spawning activity occurred slightly later in October, between October 10th and 12th. In 1999 and 2000, approximately 40% of the total observed redds were constructed by the end of the second week in October. In 2001, 74% of the total observed redds were counted by the end of the second week in October.

The peak week for chinook spawning in 2001 was comparable to peak counts of chinook from the historic run timing curve (Figure 3). The peak redd count as a proportion of the 2001 total was quite pronounced with 30% of the total observed redds formed during the peak week. This pattern is comparable to 1999 when 29% of the total observed redds were counted between Oct. 3rd and Oct. 9th. Peak data from 2000 are more comparable to the historic run curve where peak week counts accounted for 17% of the total run. However, the escapement in 2000 was a record low and this could influence the temporal distribution of redds.

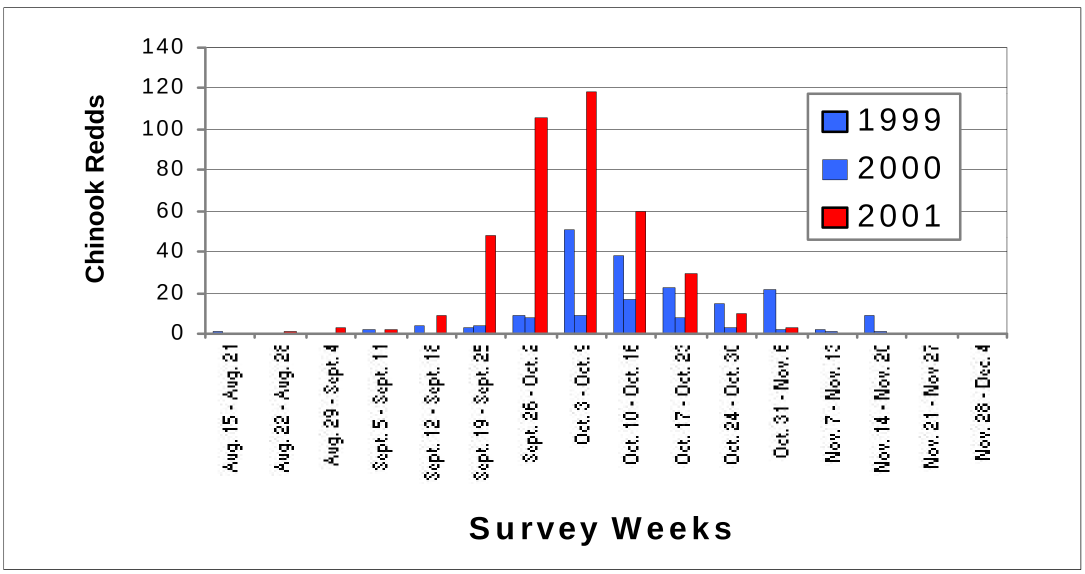

Figure 2. Temporal distribution for Cedar River chinook spawning activity 1999, 2000 and 2001.

The apparent differences between 1999 and 2001temporal redd distributions and the historic run timing curve are not definitive because differences could be explained by contrasting survey protocols. Live count survey observations include migratory and pre-spawn individuals whereas active redds only represent individuals that are in the act of

spawning or spawned out. This difference could account for cases in which the temporal distribution of active redds appears to lag slightly behind the historic run curve.
The historic run curve suggests that a relatively small proportion of the Cedar River chinook population spawns after mid-November. However, in 1999 even though spawning activity had declined substantially by mid-November, the nine redds identified on November 19th indicated that some chinook were still spawning when surveys were discontinued due to prolonged, elevated instream flows. This notion is supported by the sighting of one adult chinook near the mouth of Peterson Creek on November 23rd, 1999 (Kollin Higgins, personal communication). In 2000, the last redd was identified on November 16th and in 2001the last redd was observed on November 9th. In both years (2000 & 2001), chinook redds were not observed by WDFW or MIT fish count crews after redd surveys were discontinued. Although 1999 seemed to have a relatively protracted spawning period, the completion of spawning in 2000 and 2001 occurred in mid-November which is in agreement with the characterization of run timing contained in the historic run curve.

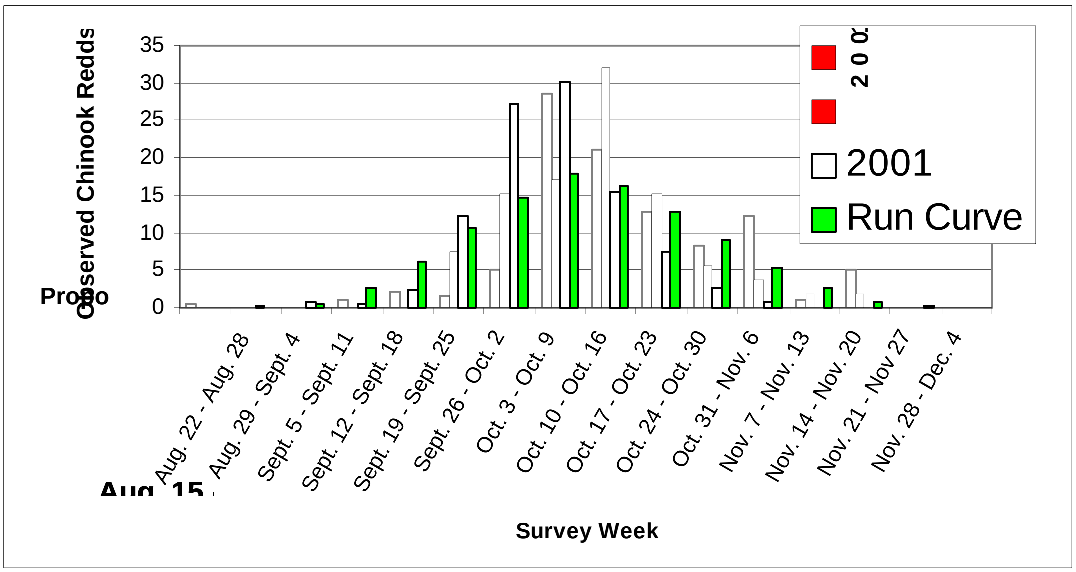

Figure 3. Temporal distribution of Cedar River chinook spawning activity as a proportion of the total 1999, 2000 and 2001 redd counts including comparison to the historic Cedar River chinook run curve.

Redds spawned in tributaries (Taylor and Walsh Creeks) accounted for a small component of the total redd count in 2001 (2%). Tributary surveys in previous years (1994-2000) have identified only 2 chinook redds in sampled tributary streams (Priest 2002). In 2001, all observed redds in tributaries were spawned between the first few days in October and October 24th.

Spawn timing trends for west coast fall chinook show that spawn timing tends to occur earlier as one moves north through the range of natural chinook distribution. Linear regression analyses of median chinook spawn time vs. latitude of spawning habitat (Healey, 1991) suggests that Cedar River chinook would exhibit a median spawn date that occurs in the last week of September or the first week of October. Spawn timing observations collected for Cedar River chinook in 1999, 2000 and 2001are in agreement with this prediction. Nearby chinook populations such as the Green and Snoqualmie River stocks also typically experience a median spawn time in early to mid-October. Despite differences between flow levels during chinook spawning periods in 1999, 2000 and 2001(Appendix B), the beginning, peak and end of annual spawning periods are quite similar.

Spatial Distribution and Habitat Characteristics for Cedar River Chinook Redds; 1999, 2000 and 2001

Longitudinal Spatial Distribution (by River Mile) of Observed Cedar River Chinook Redds; 1999, 2000 and 2001

In 2001, Cedar River chinook spawning activity was observed throughout the available river miles (below Landsburg) with the exception of the two miles of mainstem habitat immediately above Lake Washington (Figure 4). Observed redds above RM 5 accounted for 385 out of 390 total observed mainstem/sidechannel redds although the vast majority of chinook redds located in areas above RM 9 (82%) (Figure 5). Only 71 of the 390 observed Cedar River redds (18%) were located in habitats below RM 10 and the highest redd concentrations were observed in river miles 10, and 14 through 18. Many more chinook redds were spawned in the upper 3 miles of mainstem habitat in 2001 in comparison to prior survey years. Two of the redds observed in the uppermost mainstem reaches were spawned immediately below the Lake Young's Aqueduct crossing at RM 21.4. In 2001, mean number of mainstem chinook redds per river mile was 17.7 redds per mile (SE = 3.1) with a range of 0 to 47 redds per mile (Figure 4).

Tributary redds in 2001 were located in Taylor and Walsh Creeks. The redds in Taylor creek were located above the 1st Maxwell Road Bridge, with two of these redds occurring within a recent restoration project conducted by King County. The redd in Walsh Creek was located within 1,000 feet of the confluence with the Cedar. No tributary chinook redds were observed in 1999 or 2000.

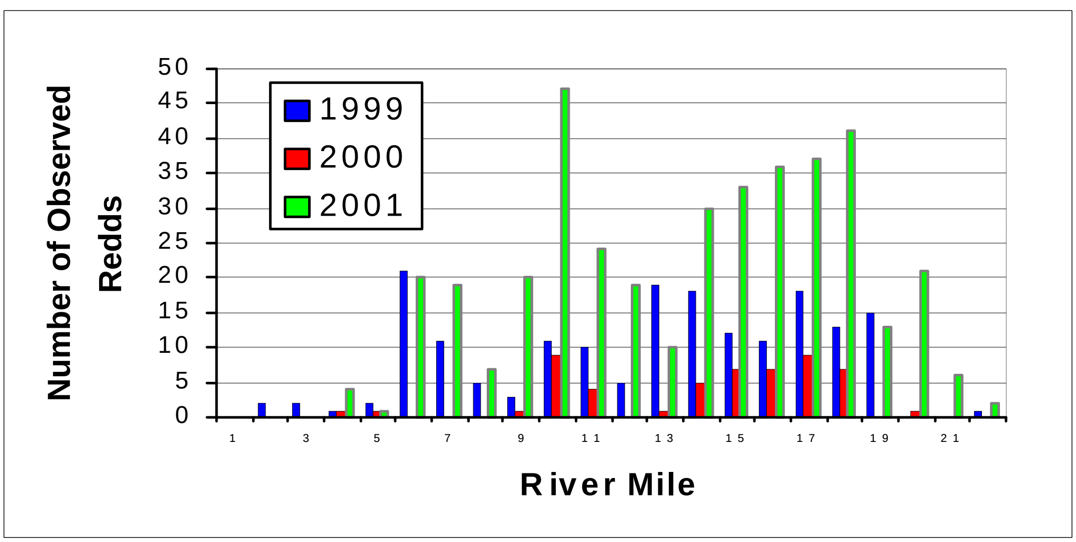

Figure 4. Longitudinal spatial distribution of observed Cedar River chinook redds by river mile 1999, 2000 and 2001.

Cedar River chinook spawning activity was concentrated in reaches above RM 9 for survey year 2000 (Figure 4). Only 3 of the 53 observed redds (6%) were located in habitats below RM 10 and the majority (66%) of the observed chinook redds were located in mainstem habitat between RM 14 and RM 18 (Figure 4a). Due to the record low escapement of chinook, the longitudinal spatial distribution of redds was discontinuous with many river miles devoid of any observed spawning activity (i.e. RMs 1,2,3,6,7,8,12,19,21,21.8). In 2000, mean number of chinook redds per river mile was 2.4 redds per mile (SE = 0.7) with a range of 0 to 9 redds per mile (Figure 4).

In 1999, the Cedar averaged 8.2 redds/mile (SE = 1.5) with a range of 0 to 21 redds per mile. Over 90% of the observed chinook redds in 2000 were located between RM 10 and RM 18 compared to 65% of the 1999 redd observations (Figure 4a). The proportion of redds in the lower half of the river was substantially larger in 1999 and 2001 than 2000 when only 6% of the observed redds were located below river mile 9.

Appendix A provides maps for chinook redd locations in the Cedar for survey years 1999, 2000 and 2001. The maps give general locations of chinook redds and should only be used to illustrate an overall distribution pattern for chinook spawning activity (i.e. exact locations are not adequately represented at this scale).

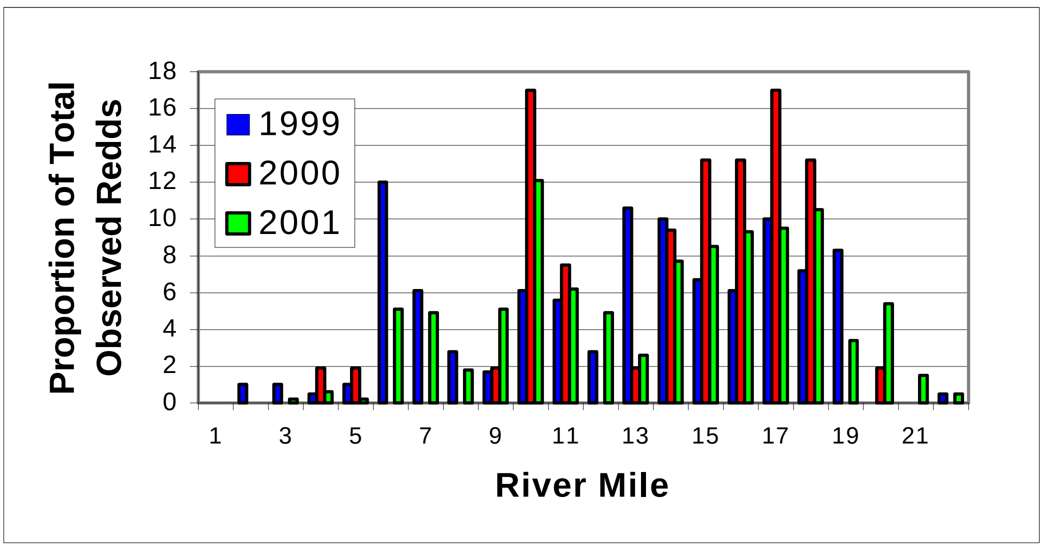

Figure 5. Proportion of observed chinook redds by river mile, Cedar River 1999, 2000 and 2001

Chinook redd locations by river mile in 2001 were similar to data from previous years in that the vast majority of redds were located above river mile 9 and, proportionately, relatively low numbers of redds were observed in the lower 4 and the upper 2 river miles (Figure 4). However, differences included a large number of redds in river mile 10 compared to previous years and a substantially higher total of redds in the upper 3 river miles than in previous years (although still a small proportion compared to other river miles). River miles 14-18 have consistently had a high proportion of their respective annual redd counts (Figure 5) which may suggest that spawning habitat in these reaches has higher quality and/or quantity than the other accessible river miles in the Cedar. This pattern may also be a result of poor spawning gravel availability in the upper 3 river miles which may force chinook that migrate to the passage barrier (aqueduct) in the upper river to move downstream to find conducive spawning areas. The planned construction of fish passage facilities will allow a more thorough conclusion regarding the apparent propensity for chinook to spawn in river miles 14-18.

In 2001, spawning areas in the upper three miles of mainstem habitat were used at proportionately higher levels than what has been observed in previous years. In the near future, fish passage facilities will allow access for chinook, coho and steelhead to spawning habitats above Landsburg and the Lake Youngs Aqueduct. The number of chinook redds in the upper three miles of mainstem habitat and the existence of two redds immediately below the Lake Youngs Aqueduct in 2001, indicate that chinook may readily use the anticipated fish passage facilities once they are available. In addition, one of the redds below the aqueduct was spawned at flows of approximately 100 cfs (gage below diversion). The existence of this early September redd, at the uppermost portion of the available mainstem habitat, demonstrates that that chinook spawning migrations in the Cedar mainstem were not obstructed by the 2002 summer flow regime (Appendix B).

Although instream flow levels in 1999 and 2001 were relatively elevated in November as compared to 2000, the effects of this difference on redd distribution were not definitive because the escapement in 2000 was a magnitude lower (record low return) than 1999 and 2001. Many river miles did not contain observed chinook redds in 2000 despite the fact that redds were found in the same river miles in 1999 and 2001. Therefore, any difference in longitudinal redd distribution between year 2000 and 1999 or 2001could have been attributed to the inability for 53 redds (year 2000 total) to fill the available spawning habitat and was not likely a result of instream flow levels or available spawning habitat.

Redd Clusters

As in 1999 and 2000, redd distribution in 2001 was comprised of redd aggregations (clusters) and individual redds that were relatively isolated from all other chinook spawning activity (Appendix A). A cluster was defined as a group of redds in which each redd is not separated from its closest neighboring redd by more than 10 meters.

In 2001, the mean number of clusters per mile was 3.3 (SE = 0.6) with a range of 0 to 7 clusters per mile. The mean number of redds per cluster was 4.2 (SE = 0.4) with a range of 2 to 17 redds per cluster.

In 2000, the mean number of clusters per mile was 0.6 (SE = 0.19) with a range of 0 to 3 clusters per mile. The mean number of redds per cluster was 2.9 (SE = 0.37) with a range of 2 to 6. The mean number of clusters per mainstem river mile for 1999 was 1.6 (SE = 0.33) with a range of 0 to 4 clusters per mile. The mean number of redds per cluster was 3.9 (SE = 0.63) in 1999 with a range of 2-19 redds per cluster (Appendix C).

Clustered redds comprised 79% of the total redd count in 2001 as compared to 66% and 73% of the total redds counts in 2000 and 1999, respectively. The remaining redds were found as individual redds that were somewhat isolated from any other observed chinook spawning activity. Individual redds comprised 21%, 34% and 27% of the total redd counts in 2001, 2000 and 1999, respectively (Table 1 and Appendix C).

Table I. Chinook redd distribution by river mile for clustered and individual redds, Cedar River 2001.

River Mile	Number of Redd Clusters 2001	Number of Redds per Cluster 2001	Number of Individual Redds 2001
1	0	0	0
2	0	0	0
3	0	0	1
4	1	2	1
5	0	0	1
6	4	3,2,5,3	7
7	4	3,2,2,2	10
8	3	2,2,2	1
9	4	2,6,2,2	8
10	7	15,2,2,4,10,7,2	5
11	7	4,5,3,3,4,3,2	0
12	3	5,5,5	4
13	3	2,2,2	4
14	4	2,15,2,3	8
15	7	3,4,2,3,5,6,5	5
16	7	7,4,3,5,2,4,3	8
17	6	10,2,4,2,3,8	8
18	7	2,3,2,3,2,17,4	8
19	2	8,2	3
20	2	12,5	4
21	1	6	0
21.8	1	2	0

The fact that the mean number of redds per cluster was not substantially different between return years 1999 and 2001 despite a more than two fold difference in total observed redds, indicates that spawning habitat in the Cedar is sufficient for chinook escapements that are comparable to 2001. If spawning habitat were limiting for 2001 spawners then one would expect a higher mean redds per cluster in 2001 than what was observed in 1999 because spawning chinook would not be able to spread out into other available spawning habitats.

Redd Depths

Redds were measured for redd pit and redd mound submergence depths in 1999, 2000 and 2001. Subsequent site visits, mound depth measurements and stage discharge relationships in 1999 and 2000 verified that the HCP minimum instream flow regime was adequate in those years to keep all chinook redds watered throughout incubation. However, in 2001 flows were relatively elevated later in the spawning season and 2 redds were predicted to be vulnerable to dewatering if minimum winter flows (260 cfs) were realized later in the season. The vulnerable chinook redds were spawned at 400 cfs and 475 cfs and were predicted to begin dewatering at 300 cfs and 400 cfs, respectively. Depth samples in February indicated that relative chinook mound depths had increased which was likely due to settling of redd substrate and a potential scour event during high flows (2,400 cfs, Renton gage) in late November. SPU water managers maintained flow levels above 400 cfs to protect all chinook redds from the adverse effects of dewatering throughout their respective incubation periods.

In 2001, instream flows were managed according to Seattle's Instream Flow Agreement, a component of the HCP. Minimum HCP flows are measured at the USGS gage below Landsburg Diversion. In 2001, minimum flows were directed by the high normal flow regime which increases from approximately 80 cfs (Landsburg) in early September to 330 cfs by the end of the first week in October (Appendix B). During the 2001 chinook spawning period, flows were augmented with reservoir storage to provide spawning flows that consistently met or exceeded the HCP high normal minimum flow regime (Appendix B). In early January the HCP high normal mimimum flow regime drops from 330 cfs to 260 cfs. However, in 2001 high levels of precipitation after October 10th allowed instream flows to reach levels that were well above minimum winter flows (Appendix B). Mean chinook mound submergence depth for 2001 was 32 cm (SE = 0.8) at the time of spawning, with a maximum mound depth of 119 cm and a minimum mound depth of 2.5 cm (Figure 5). Redd mound submergence depth distribution for 2001shows that a larger proportion of redds were spawned in relatively shallow water as compared to previous survey years' depth distributions. This may have been due to the fact that approximately 50% of the 2001 broodyear was comprised of 3 year old fish which tend to be smaller and may have a better ability to access shallower habitats for spawning. Continued sampling of the age/size frequency distribution of the population will provide better insight into the effect of age/size distribution on preferred chinook spawning depths.

In 2000, instream flows were also managed according to Seattle's Instream Flow Agreement. Minimum flows were directed by the high normal flow regime which increases from approximately 80 cfs (Landsburg) in early September to 330 cfs by the end of the first week in October. During the 2000 chinook spawning period, flows were augmented with reservoir storage to provide spawning flows that consistently met or exceeded the HCP high normal minimum flow regime (Appendix B). Typically, flow levels would not drop to near minimums at this time of year due to seasonal increases in precipitation. However, in the winter of 2000/2001 flows were dropped to near legal minimum levels due to the exceptionally dry weather and a below average snowpack (Appendix B). Mean chinook mound submergence depth for 2000 was 36 cm (SE 2.3) at the time of spawning, with a maximum mound depth of 79 cm and a minimum mound depth of 15 cm (Figure 6). The shallowest chinook redd mound was determined to be at risk of dewatering at a flow of 190 cfs (Landsburg) using historical stage/discharge information for the respective redd site. Therefore, the minimum flow of 260 cfs protected all redds from dewatering throughout incubation in 2000.

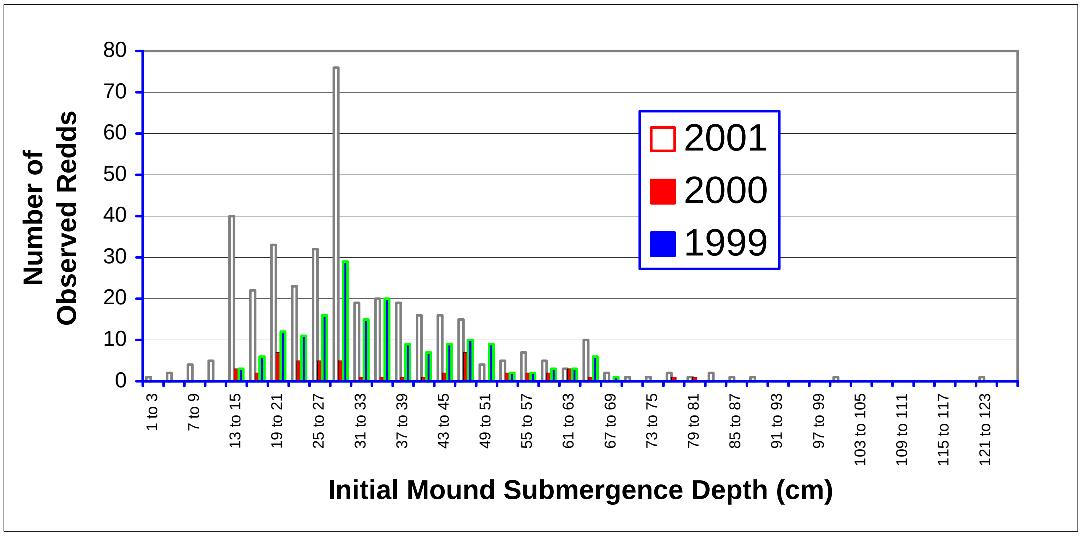

Figure 6. Submergence depths for chinook redd mounds, Cedar River 1999, 2000 and 2001.

In 1999, the minimum instream flow regime was guided by Washington State Department of Ecology's Instream Resources Protection Program (IRPP). The IRPP minimum flow regime was based on flow readings at the USGS gage at Renton where minimum flows increase from 130 cfs in early September to 370 cfs in early October. Flow augmentation during the 1999 chinook spawning season (mid-Aug - Nov.) and normal precipitation levels throughout the chinook incubation period provided flows that consistently exceeded minimums (Appendix B). In 1999, mean chinook redd mound depth was 35 cm (SE = 0.9) with a minimum and maximum mound depth of 12.7 and 68.6 cm, respectively. Stage discharge relationships for redd sites were estimated using historical relationships for specific redd sites or the Landsburg stage discharge curve in cases where reach specific stage/discharge relationships were not available. All redds were determined to be fully protected throughout incubation by the IRPP minimum flow regime in 1999. Although flows did exceed 500 cfs in early October and mid to late November, all redds observed during elevated flows were relatively deep and were not subject to dewatering risk by the minimum flow of 370 cfs. The remaining redds were all spawned at flows below 370 cfs and, therefore, could not experience any risk of dewatering at flows of 370 cfs or greater. The shallowest mound (spawned at approximately 421cfs, Landsburg) was estimated to need a minimum of 275 cfs (Landsburg) to remain fully watered (i.e. <u>all</u> redd substrate submerged) (Figure 5).

Chinook have been observed spawning in water depths spanning from as low as 5 cm (Burner 1951) to an excess of 700 cm (Chapman et al 1986). From these observations, it does not appear that spawning depth is a major limiting factor for fall spawning chinook salmon as long as there is sufficient water depth and circulation, and conducive spawning gravel for digging. Chinook redd mound depths in 2001 ranged from 2.5 cm to 119 cm with a mean mound depth of 32 cm. In 2000, data were recorded for substrate depth at the initiation of spawning and estimated mean spawning depth for Cedar River chinook salmon in 2000 was 48 cm with a range of 20 to 94 cm. Many studies suggest that shallow water is often used for spawning and the Cedar River spawning depth data are not unusual for fall spawning chinook (Table VI). In instances where spawning depths are observed to exceed five feet (Chapman et al 1986, Geist et al. 2000), the rivers are typically large (i.e. Columbia River) or redds are in artificial habitats such as dam tailraces.

Table II. Comparisons of reported chinook spawning depths.

Author	Mean Spawning Depth	Range
Briggs (1953)	33 cm	28 to 41 cm
Collings et al. (1972)		30 to 46 cm
Thompson (1972)		Greater than 23 cm
Smith (1973)	39 cm	
Bovee (1978)	30 cm	10 to 119 cm
Deverall et al. (1993)	38 cm	29 to 47 cm
Burton (2000)	35 cm	13 to 69 cm
Burton et al. (2001)	36 cm	15 to 79 cm

The shallowest redd mound observed in the Cedar River to date (1999, 2000 and 2001) was 2.5 cm deep. All redd mounds observed in 1999 and 2000 were protected from dewatering by their respective minimum flow regimes (IRPP and HCP). However, in 2001, chinook redds spawned during fall rain events at flows between 400 and 475 cfs (substantially above minimums) were vulnerable to dewatering at winter minimum HCP flows. These data are consistent with predictions made in the 2000 Cedar River chinook report that redds spawned at flows exceeding 400 cfs had the potential to become vulnerable to dewatering if minimum flows are realized later in the season. Continued chinook redd identification and monitoring will serve to help quantify the relative risks of dewatering for incubating Cedar River chinook in a variety of hydrologic conditions. Such information will allow water managers to make more informed water management decisions regarding chinook incubation protection. Future efforts will attempt to develop stage discharge relationships for shallow redds that are spawned at flows exceeding 350 cfs (Landsburg gage).

Stream Habitat Types for Redd Locations

The vast majority of chinook redds spawned in the Cedar River in 2001, 2000 and 1999 were spawned in riffle habitats (Table II). Glide habitats were also used in all survey years but for a much smaller percentage of the total observed redds than riffle habitat. Chinook tend to avoid pools and transition areas between pools and riffles (pool tailouts) for spawning sites in the Cedar. Although the proportion of redds in pools and tailouts is consistently low compared to other habitat types, in 2001 a substantial number of redds were in pools (7 out of 390).

The apparent preference for riffle habitat may be a function of relative lack of large pools (and tailouts) in the Cedar due to anthropogenic impacts such as development in the flood plain, that have promoted channel constriction, channel straightening and low levels of large woody debris recruitment. Such anthropogenic effects have augmented the overall proportion of riffle habitat and increased river gradients and velocities accordingly. For example, in 2000, the mean velocity and maximum estimated velocities for Cedar River chinook spawning were above average compared to the listed historical literature for chinook (Burton et al, 2000).

Table III. Stream habitat types for observed chinook redds, Cedar River 1999, 2000 and 2001.

	2001 Survey (390 mainstem redds)	**2000 Survey (53 redds)**	**1999 Survey (180 redds)**
Riffles	320 (82%)	38 (72%)	163 (91%)
Glides	63 (16%)	14 (26%)	16 (9%)
Pools	7 (2%)	1 (2%)	1 (0.5%)

In addition, the Cedar has been documented to have a relative lack of large woody debris recruitment which will reduce total pool area and increase average water velocity and the proportion of riffle habitats (King County 1993). The Cedar River is documented to have only 2.8 pools per mile (King County 1993) which is far below the 10 pools per mile specified as the criteria for a healthy or undisturbed stream of comparable size (NMFS, 1999). A general lack of pools may also explain why chinook redds occur predominantly in riffle habitat. Only nine redds out of 623 have been observed in pool tailouts 1999 - 2001 despite the presence of more than 60 available large pool tailout habitats. The number of redds in pools went up in 2001 but the overall proportion remained comparable to previous annual data sets. These data indicate that spawning chinook may be avoiding the headwaters and tailouts of pools. For 1999, 2000 and 2001 combined, 84% of mainstem and sidechannel chinook redds were spawned in reaches characterized as riffle habitat. Briggs (1953) reported that chinook concentrated their spawning activity in the transition areas between pools and riffles but this distribution pattern was not observed in the Cedar. Voronskiy (1972) and Chapman (1943) both reported the vast majority of observed redds (95%) as having been constructed at the head of riffles before maximum riffle gradients were realized.

Perhaps chinook in the Cedar are keying in on subgravel flow when choosing spawning sites and the apparent preference for riffles is a function of subgravel flow characteristics. Downwelling currents normally occur in areas where the latitudinal stream cross-section is convex (pool tailouts) and upwelling currents often occur in areas where the latitudinal cross-section is concave (downstream end of riffles) (Vaux 1962, 1968). Voronskiy (1972) stated that the apparent preference for subgravel flow may explain the tendency for chinook to spawn in particular locations and avoid other, superficially similar sites. The apparent preference for riffle spawning habitat in the Cedar may indicate that Cedar chinook are choosing areas of upwelling subgravel flow. Geist (2000) found that chinook redds in the Hanford Reach of the Columbia were aggregated (clustered) and occurred predominantly in areas of high hyporheic flow into the river channel (upwelling).

Although the Cedar and Columbia are not generally analogous river habitats, certainly the spawning distribution of chinook in the Cedar is aggregated with the majority of redds occurring in clusters of 2 to 19 redds (Table 1) and the majority of clusters oriented around riffle habitats (Table 6). In addition, it appears that spawning occurs in the same areas in the Cedar from year to year with the majority of chinook redds observed in 2001occurring within close proximity to chinook redd locations in 1999 and 2000. Geist also observed redds occurring in the same places from year to year in the Hanford Reach and attributed this phenomenon to subgravel flow (upwelling).

Minimum Redd Residence Time and Survey Frequency

Chinook redds that were observed to be in the initial stages of construction were sampled in 2000 and 2001 to estimate minimum redd residency time for female chinook. Typically, female chinook will remain in close proximity to their finished redd to guard against egg predation and the occurrence of subsequent redd superimposition (Neilson and Geen 1981, Neilson and Banford 1983).

In 2001, 109 (28%) redds did not have chinook associated with their location on the subsequent survey (3-4 days later). Of these, six had spawned out fish associated with the redd site on the second subsequent survey and 50 were initially observed with only one female accompanying the respective redd. Redds with fish observed on only the 1st subsequent survey after initial observation (3-4 days later) numbered 160 (42% of 385 total in biweekly reaches). Redds observed to have spawned out fish on the first and second survey (7-8 days later) following initial observation numbered 108 (28% of total). Only 8 redds had guarding fish near them for the 1st, 2nd and 3rd surveys subsequent to initial observation (10-11days later). No redds were observed to have accompanying females after the 3rd subsequent survey.

Of the 13 redds observed to be in the initial stages of redd construction in 2000, 7 had female chinook in close association one week later, one of which was observed with a guarding female for over two weeks. The remaining six redds had females with redd residency times of less than 7 days or females that were not in close association with their redd on subsequent visits. Although Cedar River chinook have been observed spawning and residing on their redds for up to 15 days, a minimum redd residence time was not established in 2000 due to the survey interval of 7 days. Our results in 2000 for redd minimum residence time should be considered a very rough approximation. Results from 2001 showed that minimum redd residency time is definitely as low as 6 days but may be as low as 3 to 4 days.

Chinook females are known to remain on their redds for 4 to 25 days after the initiation of spawning (Neilson and Geen 1981, Neilson and Banford 1983). In the Morice River, a tributary to the Skeena, chinook were observed on their redds for between 4 and 18 days (Neilson and Geen 1981). Neilson and Banford (1983) reported that Nechako River chinook females were observed on their redds from 6 to 25 days. Both chinook populations are thought to be primarily composed of stream type chinook. In both cases earlier spawning fish were reported to remain on their redds longer than later arriving fish. This could be a function of water velocity because later spawning fish are more likely to be guarding their redds during higher flows because precipitation volume tends to increase as the spawning season progresses. Higher velocities demand more energy to remain in place over redds and therefore the finite energy budget for spawning and redd residency is used faster at higher velocities.

The 2000 redd residency data made it apparent that escapement estimates derived from weekly chinook redd surveys could be improved with a higher survey frequency. For example, if some chinook are guarding their redds for 6 days or less, then redds spawned between surveys may not get counted if the female dies or leaves the redd site prior to the subsequent survey. Protocols dictate that chinook redds must be accompanied by an adult female chinook to be positively identified as originating from chinook parents. In 2001, the sheer number of returning chinook required that surveys were performed twice a week on the upper two survey reaches to accurately document the spatial and temporal spawning activity and to collect a large sample of carcasses. By eliminating every other survey from the data set, we determined how many chinook redds would have been observed without spawning fish if surveys had been done on a weekly basis as opposed to a biweekly basis. If the upper 2 survey reaches would have only been surveyed on Mondays and Tuesdays, 51 observed redds (13%) would not have been identified as chinook redds due to the absence of parent chinook upon first observation. If surveys had been performed only on Thursdays and Fridays, 64 observed redds (17%) would not have been identified as redds originating from chinook. These analyses demonstrate that a substantial number of chinook reside over their redds for less than 6 days. In addition, a small proportion (1.5%) of redds were observed to have female chinook absent from their redds on one survey only to be documented guarding their redds on the subsequent survey. In 2002, the chinook return is again expected to be relatively large and surveys will be performed twice a week. If results from the survey frequency analysis in 2002 are comparable to results from 2001, then perhaps future surveys could be performed weekly with an escapement adjustment factor that compensates for redds missed due to the longer survey interval. However, if the proportion of missed redds is highly variable when compared to the 2001analyses, surveys may be best performed with a frequency of twice a week.

Spawers per Redd

In 2000 and 2001, chinook redds that were initially observed with actively digging females or in the accompaniment of more than one chinook were used to estimate the mean number of chinook per redd. Chinook redds observed with actively digging females or two or more adult fish in 2001, totaled 261 out of 385 sampled redds. Mean number of fish per redd was 3.2 (SE=0.09) with a range of 2 to 9 fish per redd. The majority of the sampled redds in this analysis had 2 or 3 chinook when first observed.

For the 39 redds observed with digging females and/or multiple adult fish in 2000, the mean number of fish per redd was 2.9 (SE = 0.15) with the majority of redds having 2 or 3 associated chinook. The maximum number of spawners observed over a single redd was 5. In 1999, these data were not recorded but an observation of 6 fish over an individual redd was noted. The number of fish per redd cannot be used to calculate total run size because males can spawn with more than one female and, to a lesser extent, females may spawn more than one redd.

Occurrence of Chinook Redds in the Vicinity of the Sockeye Broodstock Collection Facility

The WDFW drafted a new operational protocol for the Cedar River sockeye broodstock collection facility (SBCF) in 1999. The augmented protocol was approved by the Cedar River Sockeye Technical Committee to avoid and minimize potential chinook migration delays and to discourage spawning activity directly below the SBCF.

In 2001, the SBCF was installed at RM 6.5 on September 3rd. No chinook redds had been observed below the SBCF site prior to installation. Between the times of installation and removal of the SBCF, 36 redds (9% of total) were spawned between RM 6.5 and the mouth of the Cedar and 362 redds (91% of total, including tributary redds) were spawned upstream of the SBCF. Of the 36 chinook redds observed downstream of the SBCF, 5 were spawned between the SBCF and the outlet of Cavanaugh Pond. One of the five redds spawned near the SBCF was within 10 meters of the weir itself. The other four chinook redds located between the SBCF and the Cavanaugh Pond outlet were located between 50 meters and 100 meters below the SBCF. All five redds spawned between the SBCF and the Cavanaugh Pond outlet were spawned between September 25th and October 9th. Mainstem redds upstream of the SBCF averaged 22.8 redds per river mile as opposed to 5.5 redds per river mile for redds downstream of the SBCF. No redds downstream of the SBCF were spawned in tributaries.

In 2000, the SBCF was installed at RM 6.5 on September 8th. No chinook redds had been identified prior to the SBCF installation. Only two redds (4%) were identified below RM 6.5 in 2000. Both of these redds were found on October 5th in RMs 4 and 5, respectively. In 2000, there were no chinook redd observations within the immediate vicinity of the SBCF. The closest redds were approximately 2 miles downstream of the SBCF and 2 miles upstream of the SBCF. Redd Survey crews observed two chinook in the immediate vicinity (within 25 meters) of the SBCF both of which were observed upstream of the facility. No chinook were observed immediately below the SBCF during chinook redd surveys in 2000(Burton et al. 2001).

In 1999, the SBCF was installed on September 23rd. Ten redds were identified above river mile 6.5 before the SBCF installation. A minimum of nine redds were constructed between September 23rd and October 2nd and all of these were located upstream of RM 6.5. Between October 2nd and November 15th, 34 redds were constructed below RM 6.5 and 118 redds were constructed above RM 6.5. On November 12th, elevated instream flow levels and mobilized large woody debris caused the SBCF to lose physical integrity. Removal of the SBCF structure was performed on November 15th. After November 15th, 8 redds were constructed above RM 6.5 and one redd was constructed below RM 6.5 (Burton, 2000). Redds observed above RM 6.5 in 2000 totaled 51 (96% of total) with only 2 redds (4%) constructed below the SBCF. In 1999, 145 (81% of total) redds were observed above the SBCF and 35 redds (19%) were observed below the SBCF. Redd counts in 2000 averaged 0.4 redds per mile between RM 1 and the SBCF and 3.3 redds per mile above the SBCF. In 1999, mean redd count per mile between RMs 1.0 and 6.5 was 6.4 redds per mile (SE = 3.2) as compared to a mean of 9.2 redds per mile (SE = 1.4) above the SBCF. However, in 1999, the lower mainstem below Lower Jones Bridge (RM 1.0 – RM 5.3) was not sampled with the same frequency as the rest of the river and some redds may have been missed. Therefore, the number of redds in the lower river may have been slightly underestimated. In addition, late-spawning chinook may tend to spawn in the lower river. However, this notion is not supported by the 2000 longitudinal distribution data. In 2000, the lower river was surveyed with the same frequency as the rest of the mainstem habitat and there were no redds observed below RM 9 after October 5th. It should be noted that, of the 21 redds observed in river mile 6 in 1999, nineteen of them were found in a 100-foot reach located at RM 5.3. A comparable redd concentration that included 16 chinook redds was observed in RM 13 (1999).

In 1999, the SBCF was removed on November 15, at which time there were no observed redds in the immediate vicinity (within 25 meters) of the SBCF site. However, there were two clusters of redds located approximately 110 meters and 140 meters downstream of the SBCF, respectively. The closest cluster consisted of 4 redds and the lower cluster consisted of 2 redds. The clustering of these redds was consistent with clustering elsewhere in the river as indicated by similar clusters in river miles 10, 11, 14,15,16,17,18, and 19 (Table 1). Although velocity and substrate measurements were not collected in 1999, depth, velocity, substrate size and general reach and riparian characteristics for the two clusters downstream of the SBCF appeared to be within the ranges observed at other chinook redd cluster sites.

The fact that the vast majority of chinook redds observed in 1999, 2000 and 2001 were located above the SBCF indicates that most chinook are migrating and spawning successfully above the weir. In addition, very few redds have been observed within 0.5 miles of the SBCF despite the fact that conducive spawning habitat is available in this area. These facts suggest that the new protocols implemented in 1999 are relatively successful in preventing substantial delay and obstruction of chinook spawning migrations in the Cedar. Those redds that have been observed near the SBCF have appeared to be spawned in areas that are comparable in depth, velocity and substrate size to most other redd sites in the Cedar mainstem. However, it is possible that some of the spawning below the weir may have been as a result of migration delay by operation of the weir. The one redd spawned in the immediate vicinity (within 25 meters) of the weir in 2000 was spawned on or around September 25th, in the middle of the channel within 3 meters of a steelhead redd location from spring of 2000. The proximity of this redd to a previous steelhead redd location is important because steelhead and chinook tend to spawn in the same spawning habitats in the Cedar. Therefore, the existence of a steelhead redd near the site of the closest chinook redd to the SBCF indicates that, although the redd location may be a result of influences from the weir, the habitat at the site is conducive to successful salmonid spawning and incubation.

Incidence of Redd Superimposition on Chinook Redd Mounds

In 1999, the sockeye escapement estimate for the Cedar River was approximately 22,000 adult sockeye. Of the 180 chinook redds observed in 1999, five were observed to experience sockeye spawning activity within close proximity (within 10 meters) of chinook redds. Only one chinook redd was observed to experience sockeye redd superimposition. These observations instigated questions regarding the potential for sockeye spawning activity to affect incubating chinook. For example, how would increased numbers of spawning sockeye affect the potential for interactions between spawning sockeye and incubating chinook? This may be an important source of chinook mortality assuming sockeye redd depths are deep enough to result in damage or displacement of chinook eggs. However, it is important to note that spatial overlap of sockeye and chinook redds is not necessarily an indication of damage or displacement of incubating chinook. Chinook redd superimposition on previously spawned chinook redd mounds probably has a larger impact on an incubating chinook than sockeye redd superimposition because chinook tend to dig deeper and can move larger substrates. Spawning chinook superimposed redds on 22 (12%) incubating chinook mounds in 1999.

In 2000, the Cedar River sockeye returns were expected to be an order of magnitude larger than the estimated 1999 escapement. With a larger sockeye escapement, the potential for interactions between spawning sockeye and incubating chinook redds could have been increased substantially from the proportional affects observed in 1999. Additionally, further increases in annual sockeye escapements are expected after the proposed permanent Cedar River sockeye hatchery is constructed and operational. Therefore, further investigation into this issue was deemed prudent. Regular surveys were performed to formally document the potential for impacts to incubating chinook from spawning sockeye. Weekly observations were made for 52 out of 53 chinook redds to determine the proximity and extent of sockeye spawning near (within 20 feet) incubating chinook. Twenty-two (42%) of the observed redds in 2000 had no sockeye spawning activity within 20 feet of their respective redd mounds. Twenty-four chinook redds (46%) had at least one sockeye redd within 20 feet of their respective mounds. Six chinook redds had sockeye redds superimposed on or overlapping with their mounds (11% of the observed chinook mounds).

Many chinook redds had more than one sockeye redd in close proximity to their respective mounds. Sockeye redds that were adjacent to chinook redds tended to be located between the shoreline and the observed chinook redd. Five sockeye redds were constructed in or on the edge of the redd pit of previously spawned chinook redds and were not documented to be superimposed on the mound. There were 65 sockeye redds observed outside a chinook redd perimeter but within 20 feet of the chinook redd. Of the six chinook redd mounds that were observed to experience sockeye redd superimposition, three chinook redds contained two superimposed sockeye redds and three contained one superimposed sockeye redd.

Of the nine sockeye redds spawned on chinook mounds, three were situated directly on and fully contained by their respective chinook mounds. The remaining six superimposed sockeye redds had redd mound perimeters that partially overlapped chinook mounds.

In 2000, all chinook redds with superimposed sockeye redds were spawned between October 2nd and October 12th at instream flow levels between 300 and 400 cfs at the USGS gage below Landsburg (Appendix B). Five of six of the impacted chinook redds were spawned in reaches described as glides. Glide habitats accounted for 26% of the observed chinook redds in 2000.

For chinook redds with superimposed sockeye redds in 2000, the mean estimated proportion of chinook redd surface area that was affected by spawning sockeye was 21.8 % (SE = 2.2%) with a maximum 28% and a minimum of 14%. The mean depth of superimposed sockeye redd pits relative to the surface of the chinook mound was 5.1 inches (SE = 0.2). The maximum and minimum depths for superimposed sockeye redd pits were 6 and 4 inches from the chinook mound surface, respectively.

It is important to note that, despite widespread sockeye spawning in the Cedar mainstem, sockeye spawning activity was typically absent from the areas containing chinook redds prior to the observed chinook spawning activity in 2000. Only one chinook pair was observed spawning in areas where sockeye were actively digging. All chinook redds with sockeye redds in their redd pits were in areas previously devoid of sockeye redds and 5 of 6 of the chinook redds with superimposed sockeye redds were spawned in areas that had no observed sockeye spawning activity until chinook redds were constructed. In addition, areas that contained observed chinook redd clusters in 1999 but not 2000 were densely populated with spawning sockeye throughout the observed chinook spawning period in 2000. These areas tended to have concentrated sockeye spawning activity with many redds from early spawning sockeye experiencing redd superimposition from subsequent sockeye spawners. In 2000, only 3 (6%) chinook redds experienced redd superimposition from other spawning chinook.

In 2001, the large escapement did not allow surveyors time to estimate distances between chinook redds and sockeye redds that were in close proximity. Only instances where sockeye redds were superimposed on or overlapping with incubating chinook redd mounds were documented. Of 390 chinook redds located in the Cedar mainstem habitat, 137 chinook redd mounds (35%) were observed to experience varying levels of sockeye redd superimposition. Visible affects on chinook redd mounds ranged from redds with one small sockeye redd overlapping the respective chinook redd mound to chinook redds that were indistinguishable after multiple sockeye redd superimposition events. Sockeye redd superimposition was observed from September 29th through the completion of surveys on November 15th. Sockeye tend to continue spawning in the mainstem into January so this proportion should be viewed as a minimum. In addition, 31 chinook redds (8% of total) were partially or completely superimposed by redds from subsequent chinook spawners. As in 2000, chinook redds tended to be constructed away from areas where sockeye were spawning and then sockeye moved in over chinook mounds after the departure of parent chinook.

Prior observations (1999 and 2000) were made in years where either sockeye escapement (1999 22,000 fish) or chinook escapement (2000 120 fish, 53 redds) were at their historical minimums. In 2001, sockeye counts indicated a more average escapement (approximately 125,000 fish) and chinook numbers were relatively high. A much higher incidence of sockeye redd superimposition in 2001 indicates that, in years with relatively good numbers of sockeye and chinook, sockeye redd superimposition can be expected to occur more often than years where one species is returning in low numbers. Alternatively, a higher rate of superimposition may be related to the size/age frequency distribution in the chinook spawning population. In 2001, chinook spawners were comprised of approximately 50% age 3 chinook. These smaller fish may have a higher propensity to overlap with sockeye salmon spawning habitats because smaller fish are less able to spawn at higher velocities and less capable of moving larger substrates.

Superimposed sockeye redds could potentially effect incubating chinook especially when disturbance to the chinook redd occurs prior to chinook egg hardening or when eggs are displaced from the redd. All chinook redds with superimposed sockeye mounds in 2000 experienced superimposition prior to October 15th. On October 8th, the HCP high normal minimum flow regime increases from 210 cfs (Landsburg) to 330 cfs (Landsburg). Although flows had exceeded 330 cfs prior to Oct. 8th, after Oct. 8th flows were consistently maintained at levels exceeding 330 cfs. Soon after this flow increase sockeye appeared to shift spawning activity towards the shore and away from areas of previous spawning activity near the center of the channel. No incidences of sockeye redd superimposition were observed on chinook redds created after October 12th , 2000. In 2001, sockeye redd superimposition occurred throughout the spawning period despite a large range of flow levels and therefore, the incidence of superimposition did not appear to be related to flow.

No data are available for depth of chinook egg deposition in the Cedar. However, prior studies in other systems suggest that chinook egg pocket depths range from 4 inches to 31 inches (Briggs 1953, Vronskiy 1972, Chapman et al. 1986). Briggs reported chinook egg deposition depths ranging from 8 to 14 inches with a mean of 11 inches. Vronskiy observed a larger range than Briggs with chinook eggs buried between 4 and 31 inches although very few eggs were recorded at depths exceeding 20 inches. Mean chinook egg depth was reported to be 7.5 inches by Chapman although egg deposition depth ranged from 4 to 13 inches. Prior studies have also documented egg deposition depths to be inversely proportional to water velocity at the time of spawning (Briggs 1953, Vronskiy 1972, Neilson and Banford 1983). Therefore, eggs tend to be buried deeper at lower flows. Veronskiy observed that chinook redds tend to have higher mounds when spawned at lower velocities and he postulated that this probably increases the subgravel circulation in the redd. Deeper egg deposition in areas with lower velocity may also be a function of particle size since lower velocity areas tend to have smaller substrate size distributions that may be more easily mobilized by digging chinook.

In 1999 and 2000, the numbers of chinook redds superimposed on incubating chinook redd mounds was 22 (12%) and 3 (6%) respectively. In 2001, only 8% of chinook mounds experienced chinook/chinook redd superimposition despite high numbers of chinook and relatively good numbers of sockeye. The variability in proportions of chinook/chinook redd superimposition indicates that higher incidences of this type of superimposition should not necessarily be expected with increased spawner abundance for chinook redd numbers between 53 and 398. To further this idea, the average and maximum chinook redd cluster size does not increase with higher numbers of spawning chinook in 2001 as compared to 1999. If the proportion of chinook/chinook redd superimposition was higher in 2001 and average and maximum cluster size was higher in 2001 than 1999, then one might suggest that spawning habitat is limited for escapements in the range observed in 2001. However, this was not the case and chinook seemed to spread out to new habitats including much higher use of tributaries as compared to historical data sets. For example, in previous years (94-2000), tributary surveys documented no more than two tributary redds per season in years where chinook escapement numbers were significantly lower than 2001 (Priest 2002). A complete absence of chinook redds in tributaries was more typical for tributary surveys prior to 2001. In 2001, tributary redds accounted for 8 of 398 redds (2%) in the Cedar River Basin.

Carcass Surveys

A total of 268 carcasses were sampled from the Cedar River in 2001; 239 of these were collected from the river during spawning surveys, 12 were sampled by the WDFW sockeye sampling crew, and the remaining 17 were collected at the Sockeye Broodstock Collection Facility. Scale samples were obtained from all 268 carcasses. There were 144 males and 124 females in the sample resulting in a 1.16:1 male to female ratio.

Age Analysis

Of the 268 scale samples collected, ages were successfully obtained for 240 fish. The remaining 28 scale samples were unreadable primarily due to scale regeneration. The sex ratio of aged carcasses was 1.18:1 males to females (130 males and 110 females). Age composition was: <1% age 2_1, 50% age 3_1, 47% age 4_1, 1% age 5_1 and, <1% age 5_2. Two 5-year-old fish migrated to the ocean as yearlings (subscript $_2$). The remaining 238 fish migrated as sub-yearlings (subscript $_1$). Table IV summarizes age composition of carcass recoveries.

Table IV. Number and percent of aged fish from 2001 Cedar River carcass recoveries.

Age	Total Number	Percent of Aged Fish
2_1	2	0.8%
3_1	119	49.6%
4_1	114	47.5%
5_1	3	1.3%
5_2	2	0.8%

We sampled approximately three times more male age 3_1 chinook than females (Table V). Conversely, we sampled twice as many age 4_1 females than males. A complete inventory of carcass data including age and sex recoveries by week is included in Appendix D.

Table V. Age, mean postorbit-hypural (POH) length (cm), minimum POH, maximum POH, standard deviation, sample size (n), and % of total chinook aged from 2001 Cedar River carcass recoveries.

	Males						Females					
Age	Mean POH	Min POH	Max POH	St.Dev.	n	%	Mean POH	Min POH	Max POH	St.Dev.	n	%
2_1	28.5	23	34	7.8	2	<1	na	na	na	na	0	0
3_1	56.1	46	64	4.1	87	36	56.2	50	64	3.6	32	13
4_1	65.4	54	75	5.9	39	16	64.2	54	81	4.8	75	31
5_1	na	na	na	na	0	0	69.3	67	71	2.1	3	1
5_2	78.0	78	78	0.0	2	<1	na	na	na	na	0	0

As indicated in Table VI below, 97% of the aged carcasses recovered were either three or four years old (1998 and 1997 brood years). This total is similar for naturally spawning chinook in the Green River in King County for brood years 1986-1995 (Tom Cropp, pers. comm.) in which 90% were ages 3_1 or 4_1. While the totals of ages 3_1 and 4_1 combined are similar in each river, the proportion of each age group within that total was much different. In the Cedar, 50% of the sample was age 3_1 and 47% were age 4_1. In the Green, the average was 26% age 3_1 and 64% age 4_1. It is likely that the large number of age 3_1 fish in the Cedar represent a strong survival for brood year 1998. This can be confirmed by continuing to obtain age structure information in the future.

Table VI. Percent of 2001 Cedar River chinook by age at maturation.

	Age at Maturation					
Brood Year	2_1	3_1	4_1	5_1	5_2	6
1995						0%
1996				1%	<1%	
1997			47%			
1998		50%				
1999	<1%					

Scale samples have been collected from Cedar River chinook in past years, but the dedicated effort in 2001 resulted in the most comprehensive sample to date. Based on the Area Under the Curve escapement estimate of 810 fish, the 268 samples represented 33% of the escapement. This is an excellent sample size yet it is still possible that some sampling bias exists.

Ideally, age, size, and sex composition determined from carcass surveys will accurately reflect the age, size, and sex composition of total escapement. However, numerous studies conclude that carcass surveys have a negative bias for males and for small fish (Neilson and Banford 1983; Pahlke 1995; Roni and Quinn 1995). Smaller fish tend to be removed by predators at a higher rate than larger fish. Also, smaller fish are less likely to be seen on surveys simply because of their size and the fact that they are more easily buried under debris or other carcasses. This would cause the smaller age three adults to be underestimated in our carcass surveys. Therefore, the true percentage of three-year-olds returning in 2001 may be slightly greater than the 50% shown in carcass survey data.

Another sampling bias is attributed to the difference in the behavior of males and females after spawning. Females tend to remain near their redds while males tend to drift downstream in a moribund state after spawning (Kissner and Hubartt 1986). Female carcasses were often found in shallow riffles or on a gravel bar just downstream of the redd. Since males tend to move downstream after spawning, they are more likely than females to drift into deep pools and settle. Depending on the morphology of the tributary, the incidence of carcasses being inaccessible in deep pools can vary greatly. Based on our observations, we concluded that the Cedar River has numerous deep pools that contained carcasses that were not visible from the raft. Therefore, the ratio of 1.16:1 males to females may be slightly negatively biased towards males.

Adipose Clipped Carcasses and Coded Wire Tags

Three sampled carcasses were adipose fin clipped and two of these had been implanted with Coded Wire Tags (CWT). Both of the CWT fish were recovered quite late in the season. One CWT marked carcass was from brood year 1997. This fish was raised at the Marblemount Hatchery and released from the Elliot Bay Seapens in 1999. The second CWT fish, was from brood year 1998. It was raised at the Portage Bay Hatchery (University of Washington) and released in the ship canal at Montlake in May of 1999. The adipose fin clipped fish with no CWT was age $3_{1.}$ Table VII summarizes the fish released in the ship canal at Montlake from brood years 1996-1998 and from the Elliot Bay Seapens from brood years 1996 and 1997. No fish were released from the Elliot Bay Seapens from brood year 1998 (pers. comm. Brodie Cox WDFW).

Table VII. Coded wire tag and adipose fin clipped fish released from Elliot Bay Seapens from brood years 1996 and 1997 and from the ship canal at Montlake from brood years 1996-1998.

Release Site	Brood Year	Release Year	cwt/ad clipped	cwt/no ad clip	no cwt/ad clipped	no cwt/no ad clip	Total releases
Elliot Bay Seapens	1996	1998	80,279	0	0	0	80,279
Elliot Bay Seapens	1997	1999	60,702	0	0	0	60,702
Montlake	1996	1997	165,011	0	15,036	0	180,047
Montlake	1997	1998	139,880	0	21,096	0	160,967
Montlake	1998	1999	118,419	0	0	0	118,419

It is important to note that all the fish released from these sites from brood years 1996-1998 were adipose fin clipped. These would have returned as three, four, or five year old adults in 2001. Since only three (1.1%) of the 268 carcasses were adipose fin clipped, we can conclude that there was little straying from these sites to the Cedar River in the 2001 season. However, hatchery origin fish that are not adipose fin clipped may stray into the Cedar River from other facilities. For instance, none of the chinook released from the Issaquah Creek hatchery or from the Soos Creek hatchery (Green River) for the 1996-1998 brood years were adipose fin clipped. However, beginning in 1999 and continuing indefinitely, all chinook from the Issaquah Creek hatchery and Soos Creek hatchery will be adipose fin clipped. These fish will be returning as three-year-olds in 2002 and will provide valuable information. When monitoring and evaluating adult returns it is very important to differentiate between hatchery strays and naturally produced chinook in the system. The return of only naturally produced chinook is fundamental information necessary to assess the productivity of the Cedar River.

Opercle punch

Thirty-seven chinook (26 males, 2 jacks and 9 females) were trapped and opercle punched at the weir between September 7 and September 20. Eight (22%) of the 37 marked chinook were recovered during carcass surveys (Table VIII). Five of 26 males and 3 of 9 females were recovered during surveys resulting in a 19 and 33 percent recovery rate for males and females, respectively.

Table VIII. Number and recovery rates of opercle punched Cedar River chinook by sex in 2001.

	Male	Female	Jack	Total
Punched	26	9	2	37
Recovered	5	3	0	8
Recovery Rate	19%	33%	0%	22%

We used the Fisher exact test to determine if there was a significant difference in the proportion of male to female carcasses recovered based on the initial opercle punched sample. Results of the test showed that the proportion of male to female carcasses was not significantly different (P=0.37), although sample sizes for recovered carcasses were very small, especially for females (Zar 1998). Although this opercle punched sample did not show a low recovery rate (i.e. negative bias) for males, we believe this data is important and in the future, we recommend that a larger proportion of fish be marked throughout the spawning season to determine if carcass counts are biased by sex, fish size, and run timing.

Otoliths

Otoliths were taken from 116 carcasses throughout the season. Otoliths were stored dry in vials for long term storage for possible banding pattern analysis at a future date. A floppy disc is included with the vials, referencing each otolith sample with age, sex, length, section of river recovered, and date of recovery.

Tagged Carcasses

Muckleshoot Tribal Biologists tagged chinook salmon entering the Hiram M. Chittenden (Ballard) Locks to determine fresh water residency durations and spawning distribution during the 2001 season. Six carcasses were recovered with these tags. The tags were returned to tribal biologists with pertinent information.

It is essential that fish managers are able to track brood years. Should a particularly strong or weak age class return relative to what is expected from a brood year, environmental conditions or other variables can be investigated to determine the cause of the unexpected return. For example, many changes have been made to the Ballard Locks to aid fish passage in recent years. Unexpected returns can help fish managers evaluate the effectiveness of these changes. Data from the outmigrant trap operated by WDFW on the Cedar River as well as ongoing smolt data collected annually at the Locks can be used in conjunction with age at maturity data to provide fish managers with further information. This information is necessary to increase our understanding of the life history and ecology of chinook salmon in the Cedar River.

Conclusion

Recovery efforts for threatened and endangered salmonids are most likely to succeed when the specific life history characteristics and habitat preferences for listed salmonid stocks are well documented. Because anadromous salmonids usually home to their natal streams for spawning, they tend to have freshwater life histories stages that are adapted to the specific habitat characteristics and selective pressures of their natal river basin. Understanding the freshwater behavior of listed salmonids as it relates to the specific habitat characteristics of their natal watershed should facilitate better restoration efforts and higher probabilities for successful recovery. For example, an understanding of the spatial distribution of spawning locations in a river basin can guide resource managers when they make decisions regarding habitat preservation and restoration. Areas where listed salmonids consistently concentrate spawning activity can be given high priority for habitat acquisition and preservation.

Detailed information regarding spawning and rearing habitat electivity, age and size frequency distributions and relative cohort survival rates can greatly improve the likelihood of successful recovery for managed stocks of salmonids. Unfortunately, many depressed and/or listed salmonid stocks have insufficient stock specific life history documentation, habitat use documentation and abundance information to make highly informed decisions regarding recovery efforts. In the Cedar River Basin, efforts to document chinook abundance, life history requirements and freshwater habitat preferences have intensified in response to the listing of the Puget Sound chinook ESU. The Cedar River chinook redd survey project is designed to be one component of a basin-wide effort to document the freshwater life history and habitat use of wild Cedar River chinook salmon.

The results of the 1999, 2000 and 2001chinook redd surveys have added significantly to our understanding of chinook spawning activity in the mainstem and tributaries of the Cedar River. The scope of Cedar River chinook surveys has expanded considerably since 1999 with successful documentation of spawning habitat characteristics and use. Additional data sets from future spawning years will allow for improved inter-annual comparisons of chinook spawning behavior and spawning habitat selection. Such comparisons will identify areas that consistently contain chinook spawning activity. Long-term trends for chinook spawning habitats can also be used to make inferences about the effects of stream flow on spawning and incubating chinook. However, flows have not differed considerably between years in the early and middle of the chinook spawning period and when flows have differed in the late part of the spawning period, record low escapement levels (2000) prevented meaningful comparisons between dissimilar years. Although redds spawned in 2000 tended to be near areas where chinook spawned in 1999, the distributions in the lower river were quite different between years with a much larger proportion of chinook spawning in the lower nine miles of river in 1999 than 2000. In 2001 flow levels were similar to 1999 and redd distribution by river mile was also generally similar. In addition, temporal spawning distributions were very similar between years with comparable flow regimes (1999 and 2001). Additional annual data sets will allow trends to be identified and future analyses will likely provide better insight into this issue. In addition, watershed specific habitat use data (i.e. velocity, depth and substrate size) could be used to develop Cedar River spawning habitat preference indices and these in turn could be used to evaluate available spawning habitat or to develop projects to augment available habitat.

In 2000, measurements regarding spawning location in the channel showed that chinook tend to prefer edge-oriented habitat. Although these measurements were not taken in 2001 due to the high escapement and other priorities for data collection, anecdotal observations verify that chinook redds tend to be located close to shore and sources of cover rather than in the middle of the river channel. Physical Habitat Simulation (PHABSIM) analyses indicate that weighted usable area for chinook spawning declines as stream flows (at Renton) increase above 375 cfs (Cascades Environmental Services, 1991). As stream flows increase, depth and velocity in the center of the channel may increase beyond levels that chinook typically use for spawning. In response to changes in spawning habitat distribution associated with increased flow, chinook may spawn closer to shore. Such behavior may have influences on the susceptibility of chinook redds to scour or dewatering. Combining our chinook redd observations with observations from ongoing scour studies conducted by USFWS may improve our understanding of the relationship between stream flow at the time of spawning and the subsequent susceptibility of chinook redds to scour during peak flow events.

In 2001, our results indicated that a substantial number of chinook redds can experience sockeye redd superimposition when sockeye escapement is relatively normal and chinook escapement is relatively high. However, specific impacts to incubating chinook were difficult to determine because chinook egg deposition depths in the Cedar River are not available and there was not enough time to measure surface area, sockeye redd pit depths or enumerate the number of sockeye redds superimposed on chinook redds. Further studies and staff resources could be delegated to provide more detailed data regarding this issue.

The utility of the Cedar River chinook redd database will certainly continue to grow with additional annual surveys that will further define variation in chinook spawning behavior. The data from these investigations may also be used for future purposes that may not be fully conceived at this time. For example, questions regarding chinook re-colonization above Landsburg Dam (after fish passage is complete) may be answered more holistically using our historical data base. If continued as a long-term project, future chinook redd surveys on the Cedar will certainly provide valuable information for chinook recovery efforts in the Lake Washington Basin and the Puget Sound ESU.

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Appendix A: Cedar River Chinook Redd Locations

Maps 1 and 2. Chinook Redd Locations in Upper Survey Reach (pipeline to Lion's Club Park) 1999 and 2000.

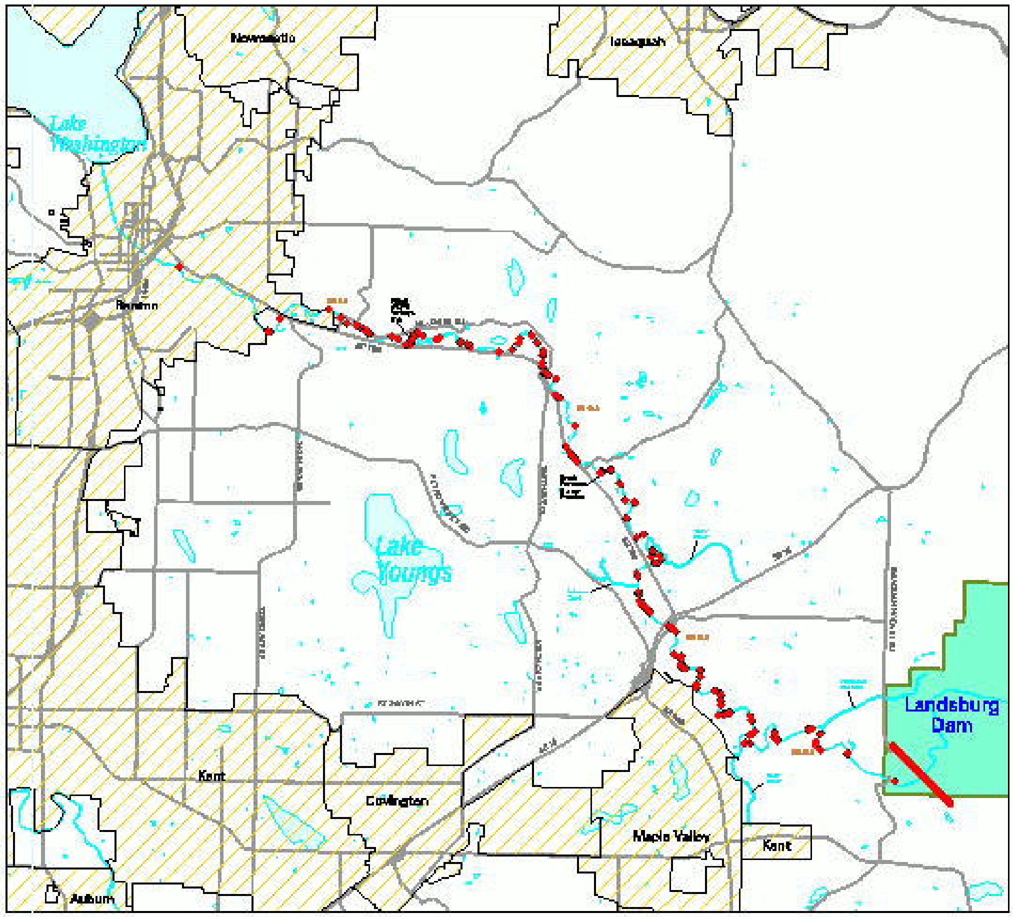
Maps 3 and 4. Chinook Redd Locations in Lower Survey Reach (Lion's Club Park to Lake Washington) 1999 and 2000.

Maps 5 and 6. Chinook Redd Locations for Upper and Lower Survey Reaches 2001.

OBSERVED CEDAR RIVER CHINOOK REDD LOCATIONS

• SURVEY YEAR 2001

Seattle
Public Utilities



Scale in Miles

0 0.5

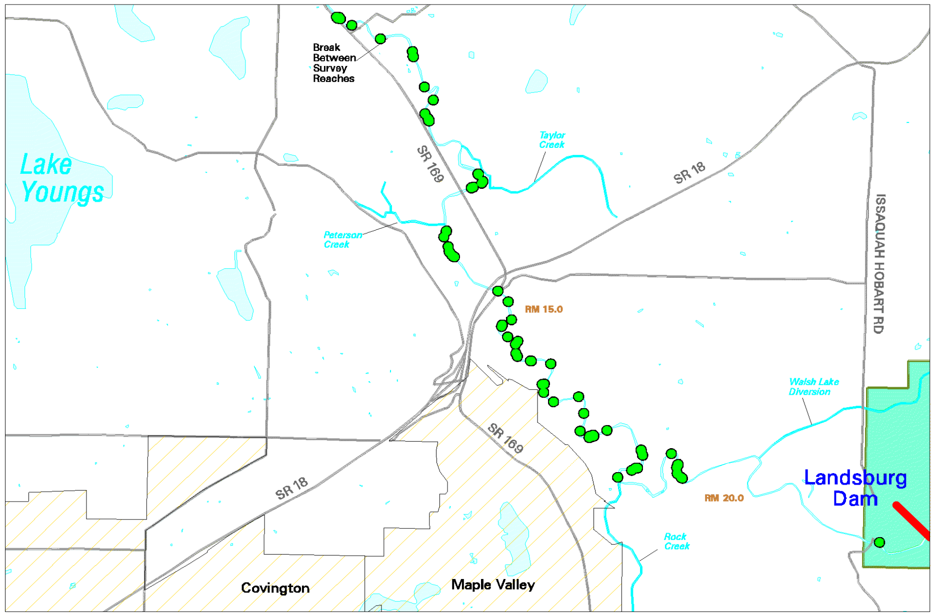
Base Map Coordinate System: State Plane NAD83-91, Washington North Zone

May 03, 2002

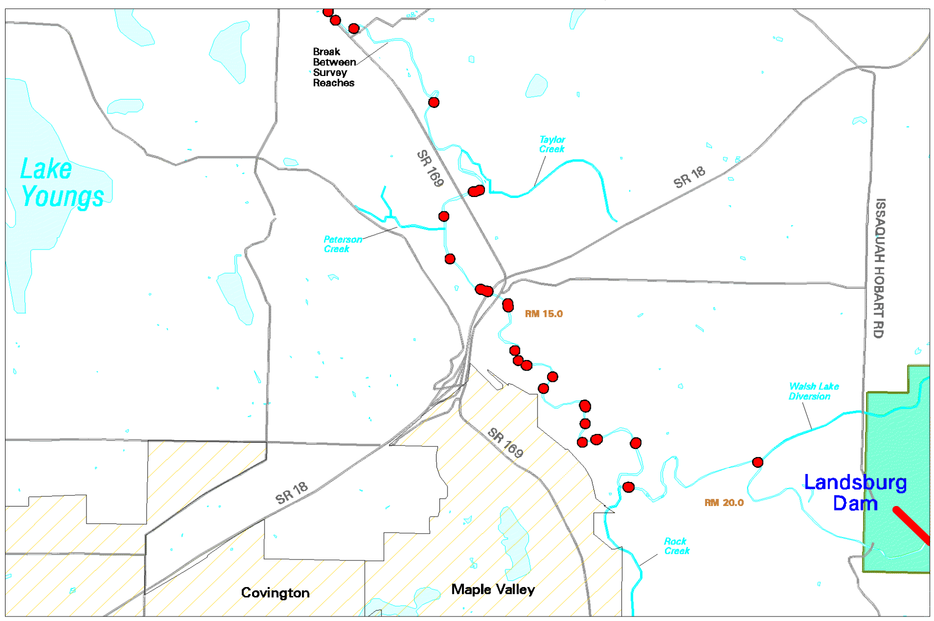
Seattle
Public Utilities

OBSERVED CEDAR RIVER CHINOOK REDD LOCATIONS

UPPER SURVEY REACH, 1999



UPPER SURVEY REACH, 2000



N
S

Scale in Miles

0 0.5

Produced by the Geographic Systems Section of the Seattle Public Utilities.

Base Map Coordinate System: State Plane NAD83-91, Washington North Zone

Streets shown on this map which are outside the boundary of The City of Seattle utility service areas have been mapped using data that is copyrighted by The Kroll Map Company. It is used with their permission and use is restricted.

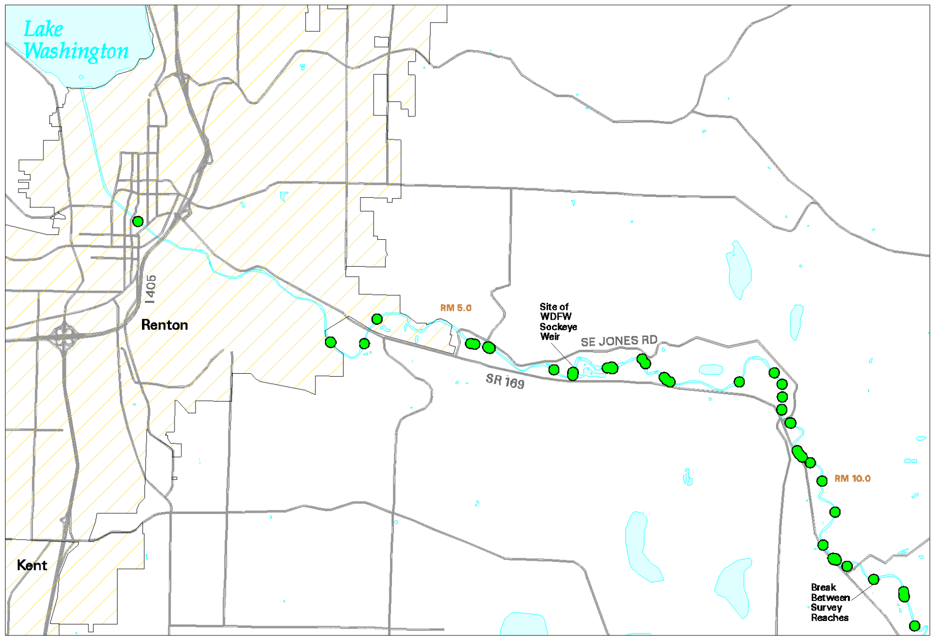
April 11, 2001

/gis1/customdev/theme/utilities/swd/stlhd85.aml

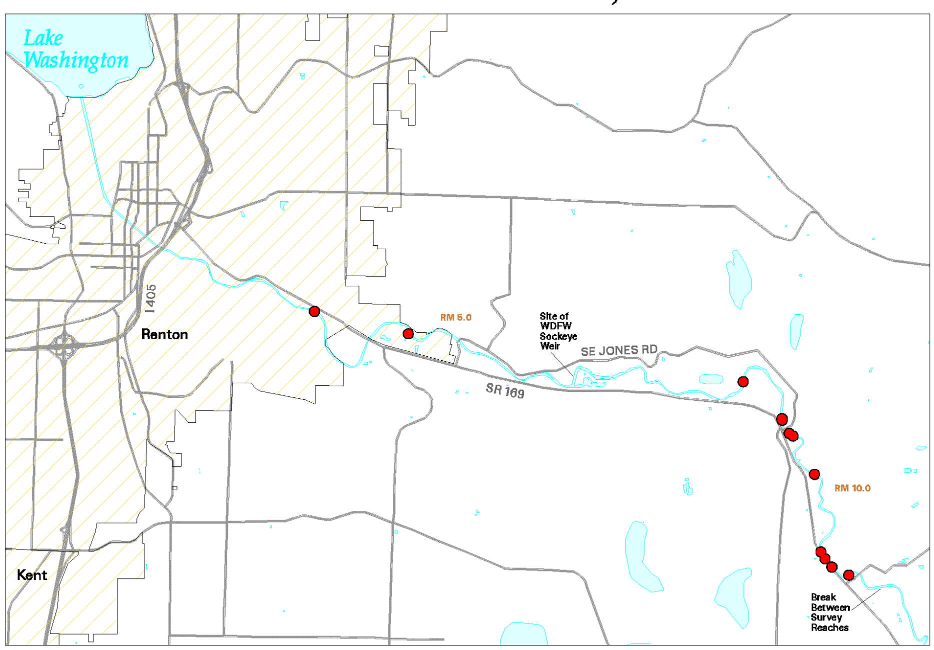
OBSERVED CEDAR RIVER CHINOOK REDD LOCATIONS

Seattle
Public Utilities

LOWER SURVEY REACH, 1999



LOWER SURVEY REACH, 2000



N
S

Scale in Miles

0 0.5

Produced by the Geographic Systems Section of the Seattle Public Utilities.

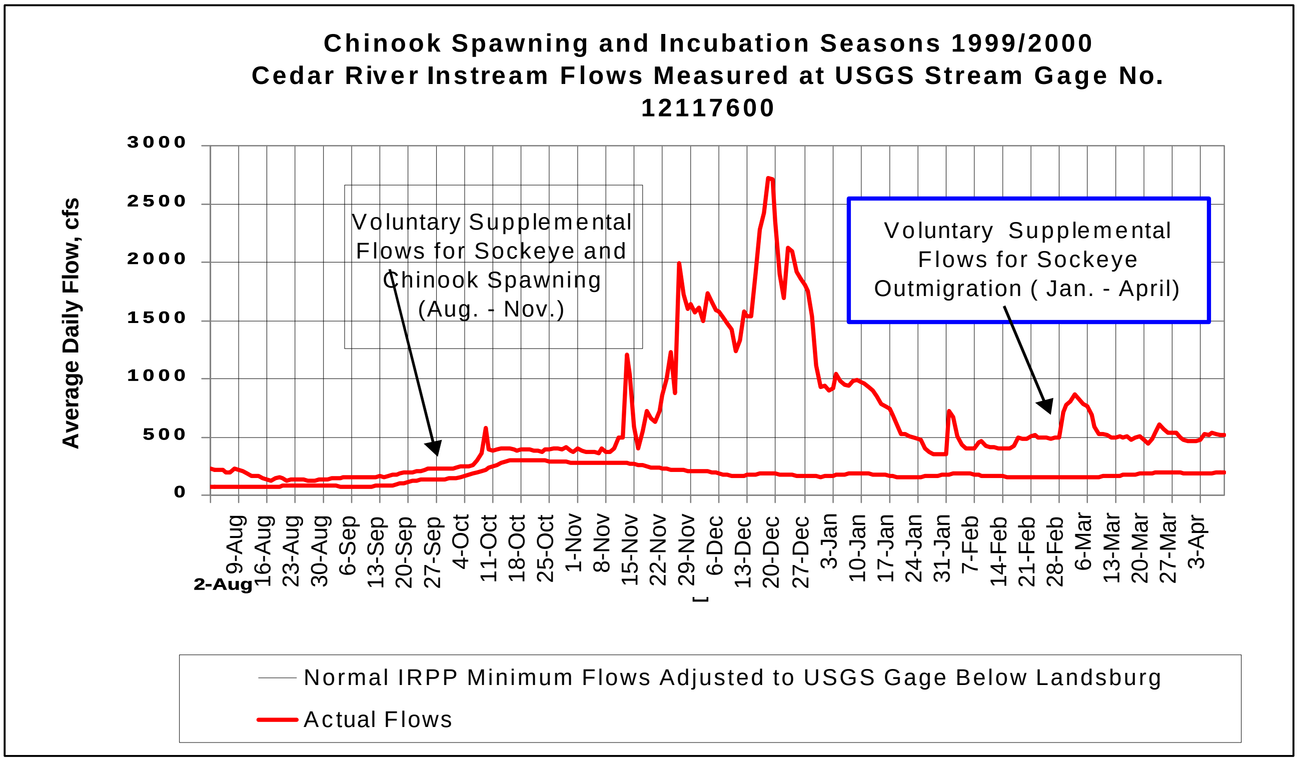
Base Map Coordinate System: State Plane NAD83-91, Washington North Zone

April 11, 2001

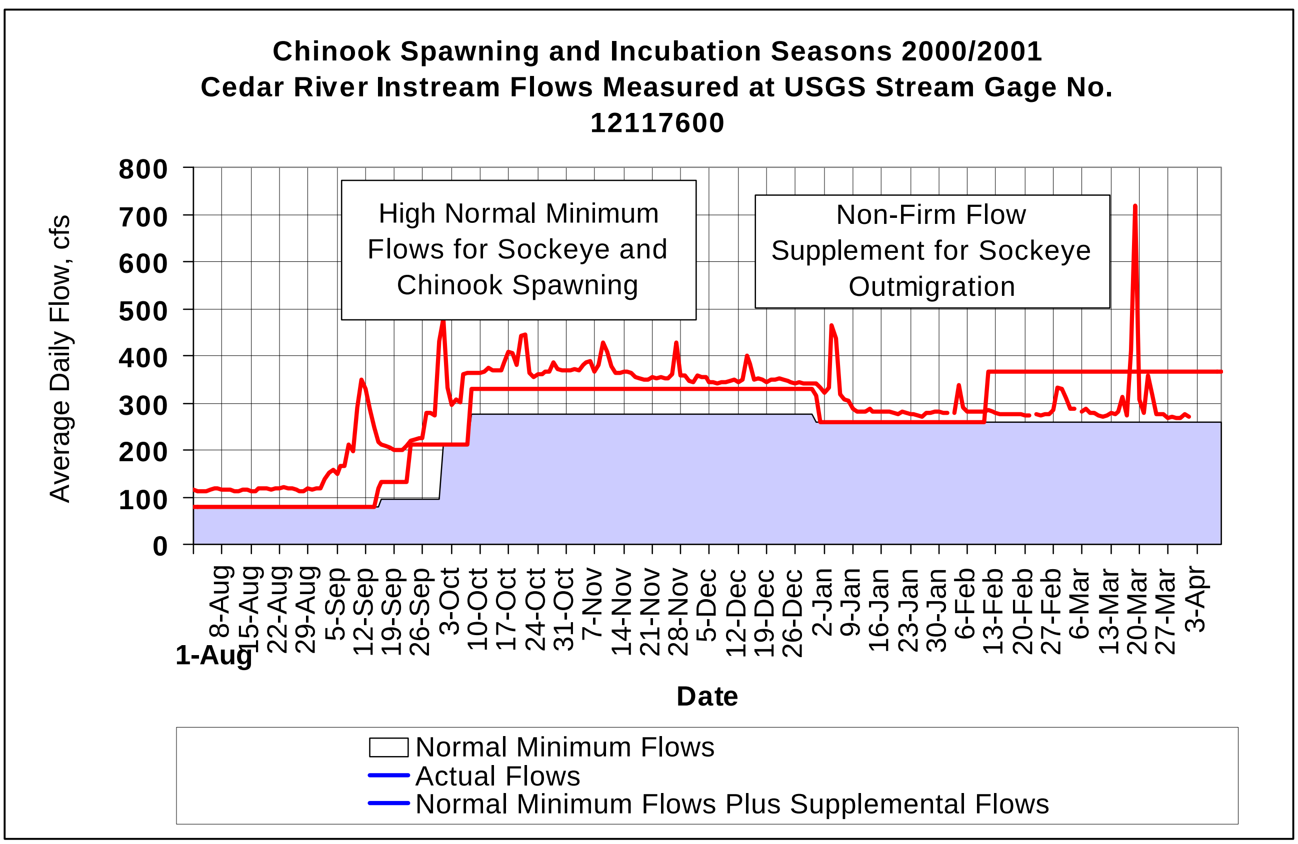
/gis1/customdev/theme/utilities/swd/stlhd85.aml

<u>Appendix B:</u>

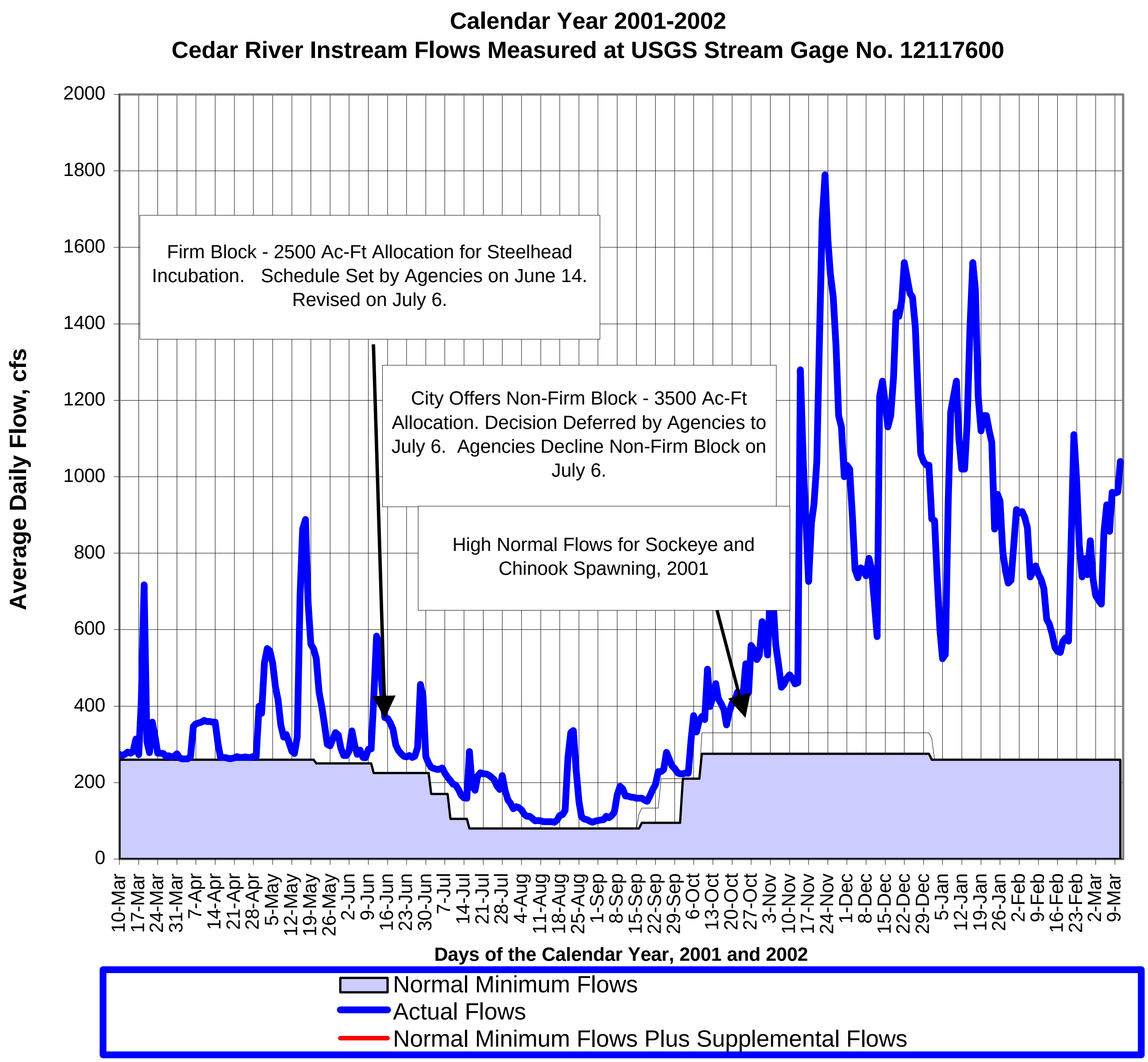
Instream Flows 1999, 2000 and 2001



Chinook Spawning and Incubation Seasons 1999/2000
Cedar River Instream Flows Measured at USGS Stream Gage No. 12117600
Average Daily Flow, cfs
3000
2500
2000
1500
1000
500
0
Voluntary Supplemental Flows for Sockeye and Chinook Spawning (Aug. - Nov.)
Voluntary Supplemental Flows for Sockeye Outmigration (Jan. - April)
2-Aug
9-Aug
16-Aug
23-Aug
30-Aug
6-Sep
13-Sep
20-Sep
27-Sep
4-Oct
11-Oct
18-Oct
25-Oct
1-Nov
8-Nov
15-Nov
22-Nov
29-Nov
6-Dec
13-Dec
20-Dec
27-Dec
3-Jan
10-Jan
17-Jan
24-Jan
31-Jan
7-Feb
14-Feb
21-Feb
28-Feb
6-Mar
13-Mar
20-Mar
27-Mar
3-Apr
Normal IRPP Minimum Flows Adjusted to USGS Gage Below Landsburg
Actual Flows



Chinook Spawning and Incubation Seasons 2000/2001
Cedar River Instream Flows Measured at USGS Stream Gage No. 12117600
Average Daily Flow, cfs
800
700
600
500
400
300
200
100
0
High Normal Minimum Flows for Sockeye and Chinook Spawning
Non-Firm Flow Supplement for Sockeye Outmigration
1-Aug
8-Aug
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
7-Nov
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
19-Dec
26-Dec
2-Jan
9-Jan
16-Jan
23-Jan
30-Jan
6-Feb
13-Feb
20-Feb
27-Feb
6-Mar
13-Mar
20-Mar
27-Mar
3-Apr
Date
Normal Minimum Flows
Actual Flows
Normal Minimum Flows Plus Supplemental Flows



Calendar Year 2001-2002
Cedar River Instream Flows Measured at USGS Stream Gage No. 12117600
Average Daily Flow, cfs
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Firm Block - 2500 Ac-Ft Allocation for Steelhead Incubation. Schedule Set by Agencies on June 14. Revised on July 6.
City Offers Non-Firm Block - 3500 Ac-Ft Allocation. Decision Deferred by Agencies to July 6. Agencies Decline Non-Firm Block on July 6.
High Normal Flows for Sockeye and Chinook Spawning, 2001
10-Mar
17-Mar
24-Mar
31-Mar
7-Apr
14-Apr
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun
30-Jun
7-Jul
14-Jul
21-Jul
28-Jul
4-Aug
11-Aug
18-Aug
25-Aug
1-Sep
8-Sep
15-Sep
22-Sep
29-Sep
6-Oct
13-Oct
20-Oct
27-Oct
3-Nov
10-Nov
17-Nov
24-Nov
1-Dec
8-Dec
15-Dec
22-Dec
29-Dec
5-Jan
12-Jan
19-Jan
26-Jan
2-Feb
9-Feb
16-Feb
23-Feb
2-Mar
9-Mar
Days of the Calendar Year, 2001 and 2002
Normal Minimum Flows
Actual Flows
Normal Minimum Flows Plus Supplemental Flows

Appendix C

Redd Locations and Redd Cluster Data by River Mile 1999 and 2000

River Mile	Number of Redd Clusters 1999	Number of Redd Clusters 2000	Number of Redds per Cluster 1999	Number of Redds per Cluster 2000	Number of Individual Redds 1999	Number of Individual Redds 2000
1	0	0	0	0	0	0
2	0	0	0	0	2	0
3	0	0	0	0	2	0
4	0	0	0	0	1	1
5	1	0	2	0	0	1
6	1	0	19	0	2	0
7	3	0	2 , 4 , 2	0	3	0
8	0	0	0	0	5	0
9	0	0	0	0	3	1
10	3	2	2 , 2 , 2	6 , 2	5	1
11	2	1	4 , 3	2	3	2
12	1	0	2	0	3	0
13	2	0	16 , 2	0	1	1
14	4	1	3 , 5 , 5 , 4	2	1	3
15	3	3	2 , 4 , 3	3 , 2 , 2	3	0
16	4	1	2 , 2 , 2 , 2	3	3	4
17	4	2	2 , 2 , 6 , 2	3 , 3	6	3
18	3	2	3 , 4 , 3	2 , 5	3	0
19	3	0	5 , 3 , 5	0	2	0
20	0	0	0	0	0	1
21	0	0	0	0	0	0
21.3	0	0	0	0	1	0

Appendix D

Raw Data for 2001 Chinook Redds and Carcasses

2001 Cedar River chinook carcass data, 2001.

Date	Statistical Week	River Mile	Sex M=1; 2=F	POH Length	Gilbert-Rich Age	Otolith	Marks, tags Label #
91101	37	5.0-13.4	2	52	3_1		
92001	38	5.0-13.4	2	71	5_1	1001	
92401	39	5.0-9.3	2	62	4_1	1002	
92401	39	5.0-9.3	1	52	unknown	1003	
92401	39	5.0-9.3	2	81	4_1	1004	
92501	39	5.0-13.4	1	63	3_1		
92501	39	5.0-13.4	2	51	3_1		
92801	39	5.0-13.4	1	53	3_1		
92801	39	5.0-13.4	1	58	3_1		
92801	39	5.0-13.4	2	60	4_1		
92801	39	5.0-13.4	1	59	4_1		
92801	39	5.0-13.4	2	68	4_1		
100101	40	13.4-21.4	1	58	3_1		
100101	40	13.4-21.4	1	57	3_1		
100101	40	13.4-21.4	1	54	3_1		
100101	40	13.4-21.4	2	65	4_1		
100101	40	13.4-21.4	2	62	4_1		
100101	40	13.4-21.4	1	63	4_1		
100101	40	6.5(weir)	2	56	3_1		
100201	40	5.0-13.4	1	23	2_1		
100201	40	5.0-13.4	2	50	3_1		
100201	40	5.0-13.4	1	56	3_1		
100201	40	5.0-13.4	1	46	3_1		
100201	40	5.0-13.4	1	52	3_1		Muckleshoot tag
100201	40	5.0-13.4	1	58	3_1		opercle punch
100201	40	5.0-13.4	2	59	3_1		
100201	40	5.0-13.4	1	51	3_1		
100201	40	5.0-13.4	2	66	4_1		opercle punch
100201	40	5.0-13.4	2	65	4_1		
100201	40	5.0-13.4	1	67	4_1		
100201	40	5.0-13.4	1	64	4_1		
100201	40	5.0-13.4	1	75	4_1		
100201	40	5.0-13.4	2	67	5_1		
100201	40	6.5(weir)	1	62	3_1		opercle punch
100301	40	5.0-13.4	2	60	3_1		WDFW sockeye crew recovery
100301	40	6.5(weir)	1	64	4_1		
100301	40	6.5(weir	2	67	unknown		

		)				
100401	40	13.4-21.4	1	53	3_1	
100401	40	13.4-21.4	2	56	3_1	
100401	40	13.4-21.4	1	56	3_1	
100401	40	13.4-21.4	1	57	3_1	
100401	40	13.4-21.4	1	54	3_1	
100401	40	13.4-21.4	1	55	3_1	
100401	40	13.4-21.4	1	52	3_1	opercle punch
100401	40	13.4-21.4	1	55	3_1	
100401	40	13.4-21.4	1	54	3_1	
100401	40	13.4-21.4	2	58	4_1	
100401	40	13.4-21.4	1	57	4_1	
100401	40	13.4-21.4	2	54	4_1	
100401	40	13.4-21.4	2	63	4_1	
100401	40	13.4-21.4	1	64	4_1	
100401	40	13.4-21.4	1	64	4_1	opercle punch
100401	40	13.4-21.4	2	52	unknown	
100401	40	13.4-21.4	1	49	unknown	
100401	40	13.4-21.4	1	55	unknown	opercle punch
100401	40	6.5(weir)	1	56	3_1	
100401	40	6.5(weir)	1	55	unknown	
100501	40	5.0-13.4	1	58	3_1	
100501	40	5.0-13.4	1	56	3_1	
100501	40	5.0-13.4	2	56	3_1	
100501	40	5.0-13.4	1	53	3_1	
100501	40	5.0-13.4	1	56	3_1	
100501	40	5.0-13.4	2	60	4_1	
100501	40	5.0-13.4	1	57	4_1	
100501	40	5.0-13.4	1	57	4_1	
100501	40	5.0-13.4	2	58	4_1	opercle punch
100501	40	5.0-13.4	1	53	unknown	
100501	40	5.0-13.4	2	63	unknown	
100501	40	5.0-13.4	2	61	unknown	
100501	40	6.5(weir)	2	61	4_1	

100801	41	13.4-21.4	2	50	3_1		
100801	41	13.4-21.4	1	58	3_1		opercle punch
100801	41	13.4-21.4	2	52	3_1		
100801	41	13.4-21.4	1	52	3_1		
100801	41	13.4-21.4	1	55	3_1		
100801	41	13.4-21.4	1	56	3_1		
100801	41	13.4-21.4	1	58	3_1		
100801	41	13.4-21.4	1	52	3_1		
100801	41	13.4-21.4	1	50	3_1		
100801	41	13.4-21.4	1	55	3_1		
100801	41	13.4-21.4	1	60	3_1		
100801	41	13.4-21.4	2	59	3_1		
100801	41	13.4-21.4	1	59	3_1		
100801	41	13.4-21.4	1	52	3_1		
100801	41	13.4-21.4	2	59	3_1		
100801	41	13.4-21.4	1	61	4_1		
100801	41	13.4-21.4	2	63	4_1		
100801	41	13.4-21.4	1	57	4_1		
100801	41	13.4-21.4	1	54	unknown		
100801	41	13.4-21.4	1	59	unknown		
100901	41	5.0-13.4	1	78	5_2	1005	
100901	41	5.0-13.4	2	73	4_1	1006	
100901	41	5.0-13.4	1	54	3_1	1007	
100901	41	5.0-13.4	1	63	4_1	1008	
100901	41	5.0-13.4	1	50	3_1	1009	ad clip-no cwt
100901	41	5.0-13.4	1	57	3_1	1010	
100901	41	5.0-13.4	2	58	4_1	1011	
100901	41	5.0-13.4	2	65	4_1	1012	
100901	41	5.0-13.4	2	62	4_1	1013	Muckleshoot tag
100901	41	5.0-13.4	1	55	3_1	1014	Muckleshoot tag
100901	41	5.0-13.4	2	67	4_1	1015	Muckleshoot tag
100901	41	5.0-13.4	1	63	4_1	1016	
100901	41	5.0-13.4	2	54	3_1	1017	
100901	41	5.0-13.4	1	78	5_2		
100901	41	5.0-13.4	2	57	3_1		

100901	41	5.0-13.4	1	60	3 1		
100901	41	5.0-13.4	2	52	3 1		
100901	41	5.0-13.4	2	67	4 1		
100901	41	5.0-13.4	2	64	4 1		
100901	41	5.0-13.4	2	62	4 1		
100901	41	5.0-13.4	1	64	unknown		
100901	41	5.0-13.4	2	56	unknown		
100901	41	5.0-13.4	1	67	unknown		
100901	41	5.0-13.4	1	48	unknown		
100901	41	6.5(weir)	1	50	3 1		
100901	41	13.4-21.4	1	65	unknown		WDFW sockeye crew recovery
100901	41	13.4-21.4	2	66	4 1		WDFW sockeye crew recovery
100901	41	13.4-21.4	2	53	3 1		WDFW sockeye crew recovery
100901	41	13.4-21.4	1	72	4 1		WDFW sockeye crew recovery
100901	41	13.4-21.4	1	63	3 1		WDFW sockeye crew recovery
101101	41	13.4-21.4	2	51	3 1	1018	
101101	41	13.4-21.4	2	56	unknown	1019	
101101	41	13.4-21.4	2	60	3 1	1020	
101101	41	13.4-21.4	1	48	3 1	1021	
101101	41	13.4-21.4	1	57	3 1	1022	
101101	41	13.4-21.4	2	54	3 1	1023	
101101	41	13.4-21.4	2	64	3 1	1024	
101101	41	13.4-21.4	1	49	3 1	1025	
101101	41	13.4-21.4	1	59	3 1	1026	
101101	41	13.4-21.4	2	59	4 1	1027	
101101	41	13.4-21.4	1	62	3 1	1028	
101101	41	13.4-21.4	2	71	unknown	1029	
101101	41	13.4-21.4	2	61	4 1	1030	
101101	41	13.4-21.4	1	66	4 1	1031	
101101	41	13.4-21.4	1	53	3 1		
101101	41	13.4-21.4	1	62	3 1		
101101	41	13.4-21.4	2	66	4 1		
101101	41	6.5(weir	2	58	3 1		

		)					
101101	41	5.0-13.4	2	58	3_1		WDFW sockeye crew recovery
101201	41	5.0-13.4	2	61	4_1	1032	
101201	41	5.0-13.4	2	63	4_1	1033	
101201	41	5.0-13.4	1	51	3_1	1034	
101201	41	5.0-13.4	2	69	4_1	1035	
101201	41	5.0-13.4	1	62	3_1	1036	
101201	41	5.0-13.4	1	55	3_1	1037	
101201	41	5.0-13.4	2	65	unknown	1038	
101201	41	5.0-13.4	2	67	unknown	1039	
101201	41	5.0-13.4	1	69	4_1	1040	
101201	41	5.0-13.4	1	55	3_1	1041	
101201	41	5.0-13.4	1	63	4_1	1042	
101201	41	5.0-13.4	1	59	3_1	1043	
101201	41	5.0-13.4	1	59	3_1	1044	
101201	41	5.0-13.4	2	58	4_1	1045	
101201	41	5.0-13.4	1	59	3_1		
101201	41	5.0-13.4	1	61	3_1		
101201	41	5.0-13.4	1	63	3_1		
101201	41	5.0-13.4	2	60	4_1		
101201	41	5.0-13.4	2	68	4_1		
101201	41	5.0-13.4	2	58	4_1		
101501	42	13.4-21.4	1	71	4_1	1046	
101501	42	13.4-21.4	2	60	3_1	1047	
101501	42	13.4-21.4	1	57	3_1	1048	
101501	42	13.4-21.4	2	56	4_1	1049	
101501	42	13.4-21.4	1	57	3_1	1050	
101501	42	13.4-21.4	2	63	4_1	1051	
101501	42	13.4-21.4	1	63	4_1	1052	
101501	42	13.4-21.4	1	57	3_1	1053	
101501	42	13.4-21.4	2	57	4_1	1054	
101501	42	13.4-21.4	2	54	3_1	1055	
101501	42	13.4-21.4	2	66	4_1	1056	
101501	42	13.4-21.4	2	59	3_1	1057	
101501	42	13.4-21.4	2	68	4_1	1058	
101501	42	13.4-21.4	2	66	4_1	1059	
101501	42	13.4-21.4	1	57	3_1	1060	
101501	42	13.4-21.4	2	68	4_1	1061	

101501	42	13.4-21.4	2	64	4_1	1062	
101501	42	13.4-21.4	2	64	unknown	1063	
101501	42	13.4-21.4	1	66	4_1	1064	
101501	42	13.4-21.4	2	64	unknown	1065	
101501	42	13.4-21.4	1	64	3_1	1066	
101501	42	13.4-21.4	1	57	3_1	1067	
101501	42	13.4-21.4	2	67	4_1	1068	
101501	42	6.5(weir)	1	56	3_1	1069	
101501	42	6.5(weir)	1	59	3_1	1070	Muckleshoot tag
101501	42	13.4-21.4	1	57	3_1		
101501	42	13.4-21.4	2	71	4_1		
101501	42	13.4-21.4	1	59	4_1		
101601	42	5.0-13.4	1	51	3_1	1071	
101601	42	5.0-13.4	2	56	3_1	1072	
101601	42	5.0-13.4	1	70	4_1	1073	
101601	42	5.0-13.4	1	63	4_1	1074	
101601	42	5.0-13.4	1	52	3_1	1075	
101601	42	5.0-13.4	1	49	3_1	1076	
101601	42	5.0-13.4	2	70	4_1	1077	
101601	42	6.5(weir)	1	51	3_1	1078	
101601	42	6.5(weir)	1	58	3_1	1079	
101601	42	5.0-13.4	1	53	3_1		
101601	42	5.0-13.4	2	57	3_1		
101601	42	5.0-13.4	1	63	3_1		
101601	42	5.0-13.4	1	62	unknown		Muckleshoot tag
101801	42	13.4-21.4	2	61	4_1	1080	
101801	42	13.4-21.4	1	71	4_1	1081	
101801	42	13.4-21.4	2	63	4_1	1082	
101801	42	13.4-21.4	1	64	4_1	1083	
101801	42	13.4-21.4	1	71	4_1	1084	
101801	42	13.4-21.4	1	64	3_1	1085	
101801	42	13.4-21.4	2	66	4_1	1086	
101801	42	13.4-21.4	1	57	3_1	1087	

101801	42	13.4-21.4	2	67	4_1	1088	
101801	42	13.4-21.4	2	67	unknown	1089	
101801	42	13.4-21.4	2	61	4_1	1090	
101801	42	13.4-21.4	2	55	3_1	1091	
101801	42	13.4-21.4	2	64	4_1	1092	
101801	42	13.4-21.4	2	58	3_1		
101801	42	13.4-21.4	2	63	3_1		
101801	42	13.4-21.4	2	59	3_1		
101801	42	13.4-21.4	2	67	4_1		
101801	42	13.4-21.4	1	68	4_1		
101801	42	13.4-21.4	2	79	unknown		
101801	42	6.5(weir)	2	70	5_1		
101801	42	6.5(weir)	1	80	4_1		
101801	42	6.5(weir)	1	63	3_1		
101801	42	6.5(weir)	1	34	2_1		
101801	42	5.0-13.4	1	77	4_1		WDFW sockeye crew recovery
101901	42	5.0-13.4	1	58	unknown	1093	
101901	42	5.0-13.4	2	64	4_1	1094	
101901	42	5.0-13.4	1	65	unknown	1095	
101901	42	5.0-13.4	2	62	4_1	1096	
101901	42	5.0-13.4	2	65	4_1	1097	
101901	42	5.0-13.4	1	66	4_1	1098	
101901	42	5.0-13.4	2	68	4_1	1099	
101901	42	5.0-13.4	2	63	4_1	1100	
101901	42	5.0-13.4	2	69	4_1	1101	
101901	42	5.0-13.4	2	72	4_1	1102	
101901	42	5.0-13.4	1	66	4_1	1103	
101901	42	5.0-13.4	1	54	4_1	1104	
101901	42	5.0-13.4	1	60	3_1	1105	
101901	42	5.0-13.4	2	56	3_1	1106	
101901	42	5.0-13.4	1	52	3_1		
101901	42	5.0-13.4	1	55	3_1		
101901	42	5.0-13.4	2	64	4_1		
101901	42	5.0-13.4	2	68	4_1		
101901	42	13.4-21.4	2	77	4_1		WDFW sockeye crew recovery
101901	42	13.4-21.4	1	67	4_1		WDFW sockeye crew recovery
101901	42	13.4-21.4	2	74	4_1		WDFW sockeye crew recovery

102201	43	13.4-21.4	1	56	3_1		
102201	43	13.4-21.4	1	53	3_1		
102201	43	13.4-21.4	2	59	4_1		
102201	43	13.4-21.4	2	61	4_1		
102201	43	13.4-21.4	2	60	4_1		
102301	43	5.0-13.4	2	68	4_1	1107	
102401	43	5.0-13.4	1	74	4_1		WDFW sockeye crew recovery
102501	43	13.4-21.4	1	65	4_1	1108	
102501	43	13.4-21.4	2	63	4_1	1109	
102601	43	5.0-13.4	1	71	4_1	1110	
102601	43	5.0-13.4	1	58	3_1	1111	
102601	43	5.0-13.4	2	62	4_1	1112	
102601	43	5.0-13.4	1	53	3_1		ad clip-cwt present(1)
102601	43	5.0-13.4	1	53	3_1		
102601	43	5.0-13.4	2	60	4_1		
102601	43	5.0-13.4	2	63	4_1		
103001	44	5.0-13.4	2	68	unknown	1113	
103001	44	5.0-13.4	2	60	4_1		ad clip-cwt present(2)
110201	44	5.0-13.4	2	66	4_1	1114	
110601	45	5.0-13.4	2	63	4_1		
110901	45	5.0-13.4	2	69	4_1	1115	
110901	45	5.0-13.4	1	64	3_1		
111301	46	5.0-13.4	1	58	4_1	1116	

37 chinook opercle punched at weir from 9/7/01 to 9/20/01
9 female; 26 males; 2 jacks
recovered: 2 - 3_1 males; 2 - 4_1 males;
2 - 3_1 females; 1 - 4_1 female;
1 unknown age male

6 Muckleshoot tagged fish

116 otoliths taken

3 ad clips, 2 with cwt's
ad clip-cwt(1)label#11851brood year 1998; released in 1999 in the ship canal @ Montlake;
reared Portage Bay Hatchery;
tag code 63-9-19

ad clipcwt(2)label#11852(brood year 1997; released in 1999 from Elliot Bay Seapens; reared Marblemount Hatchery; tag code 63-7-45